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STRENGTH OF SHIPS - ON THE NEUTRAL AXIS LOCATION

Artur Licínio de Albuquerque Ferreira da Silva

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STRENGTH OF SHIPS - ON THE NEUTRAL AXIS LOCATION

by

ARTUR LICÍNIO DE ALBUQUERQUE FERREIRA DA SILVA

Lieutenant, Portuguese Navy

B.S., Portuguese Naval Academy (1969)

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE PROFESSIONAL DEGREE OF

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NAVAL ARCHITECTURE AND MARINE ENGINEERING

at the

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ABSTRACT

This work is an attempt at determining the optimum neutral axis location in the midship section of a vessel, using as a model for the calculations a box girder, subject to several different conditions of sagging and hogging bending moments; several values of design stress are also considered and in the end what happens when lateral hydrostatic load is considered along with different values assigned to the design stress in tension and in compression is also analysed.

Thesis Supervisor: J. Harvey Evans

Title: Professor of Naval Architecture

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I want to express my gratitude to Professor Evans for his expert advice and guidance that encouraged me throughout this work.

I want to thank God for giving me the strength to proceed for many years in the path He was so kind to make available to achieve my present education.

My gratitude is here expressed to my wife as well for her patience to accompany and help me to reach my graduation.

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LIST OF SYMBOLS

a - distance between transverse stiffening members

AL - length of box girder or vessel

B - beam

BOT - thickness of the plating on the bottom

BM - bending moment

D - depth

DIBOT - distance of the bottom from the neutral axis

DITOP - distance of the top from the neutral axis

DSC - design stress in compression

DST - design stress in tension; also design stress without discrimination when DSC=DST

H - head of sea water (lateral load)

HB - head of sea water on the bottom

HM - hogging bending moment

HT - head of sea water on the top

I - moment of inertia of the cross section with respect to the neutral axis (GMI in the program)

LBS - longitudinal bending stress

S - spacing of longitudinal stiffening members

SBCRIT - critical stress on bottom

SBH - stress on bottom due to hogging

SBS - stress on bottom due to sagging

SM - sagging bending moment

STCRIT - critical stress on top

STH - stress on top due to hogging

STR - stress

STR1 - primary stress = LBS

STR2 - secondary stress

STR3 - tertiary stress

STR3B - tertiary stress on bottom

STR3T - tertiary stress on top

STRCR - critical stress

STS - stress on top due to sagging

t - thickness of theplate

T - draft

TOP - thickness of the plating on the top

TS - thickness of the side plating

TSTH - total stress on top in hogging

TSTS - total stress on top in sagging

TSBH - total stress on bottom in hogging

TSBS - total stress on bottom in sagging

INTRODUCTION

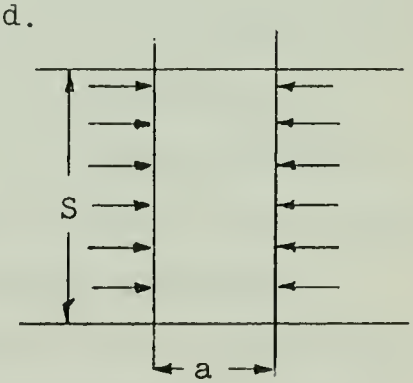
It is frequently found in the literature related with the strenght of ships such statements as:

"In general the neutral axis is expected to be at 40% of the depth (D) above the base line ... a preliminary estimate of the thickness required for the bottom plating (BOT) can be obtained from

$$1.875\left(\frac{0.4D}{0.6D}\right)2240\sqrt[3]{AL} = \frac{40300}{1+\frac{1}{950}\left(\frac{S}{BOT}\right)^{1.75}}$$

where the Montgomerie's expression is being considered to determine the critical stress (SBCRIT psi) and the short edges are assumed far apart and simply supported.

$$SBCRIT = \frac{40300}{1+\frac{1}{950}\left(\frac{S}{BOT}\right)^{1.75}}$$



$S \geq 4a$

a- distance between transverse stiffening members (inches)

1.875 accounts for a factor of safety

Tobin's expression was considered in the above formula to give the maximum permissible bending stress (LBS, psi)

$$LBS = 2240\sqrt[3]{AL}$$

We see thus that this procedure allows for an estimate of the bottom thickness to be obtained after knowing the length and assuming a longitudinal frame spacing. What may be questioned here is the reason why one assumes the neutral axis 0.4D above the base line and also the reasons behind the choice of a frame spacing.

In the following a procedure to estimate the scantlings of longitudinal members is described; this procedure can also be found frequently in the literature dealing with the subject.

..."For a particular set of principal dimensions , general arrangement and frame spacing, plate panel thicknesses for one after another of the amidships longitudinally continuous elements are selected for an assumed position of the neutral axis at 40% of the depth above the keel. The composite midship section assemblage is thentested for the adequacy of its section modulus when ranged alongside some standard value, such as given by the Load Line Regulations or some function of it. Thus the modulus is judged sufficient to limit ship bending stresses to the value previously set and incorporated into the design equations.

For all but the deepest ships the modulus will undoubtedly need to be increased and a small arbitrary increment is added to the upper deck or bottom whichever happens still to be farther from the true neutral axis location found after the first design cycle. The shift of neutral axis resulting from the scantling increment requires a compensating increment in the opposite flan-

ge with the obvious outcome that the neutral axis is shifted in reverse with attendant effect on the scantling chosen first; a cyclic process is then begun. More trials will be necessary before the match of available to required section modulus is achieved."

From this transcript, we may again note the initial statement "...for a particular set of principal dimensions, general arrangement and frame spacing..." and question whether or not the frame spacing should be chosen as an input or rather be left as a variable and be obtained as a result of a structural design procedure. It is here aknowledged though that in these procedures an acceptable solution can be worked out and each new cycle is an improvement over the precedent ones. What may be questionable though is whether the first cycle, due to the assumptions made at its beginning, has or not a strong influence in the outcome leading to a solution among the various possible ones which in the end does not lead to"the optimum design" whatever its definition may be.

It seems that this trial procedure can be looked at as a "weakness" of the structural design procedure for the determination of scantlings and it is perhaps reasonable to make some effort in order to work out a process that could give the scantlings in a direct manner and be at the same time in agreement with what can be considered "the optimum design", (usually based on economic considerations).

Nowadays much concern is given to economics in ship design and naturally the strength calculations of a ship are also made with economical optimization in mind. With this respect, we can realize that in ships structures there is a desirability to minimize structural weight and some define structural efficiency as being the least weight structure capable of resisting the loads for which they are designed.

It should be clear that the cost of construction and of maintenance and repair are inter related factors together with least weight, to be considered when bringing economics into ship structural design. Also other matters such as accessibility, weldability and availability of material must be considered as well.

In the following sections an attempt is made to obtain without any interactions the scantlings for the plating of a box girder. It is hoped that through this simple model some helpful conclusions can be made in view of their application to a vessel's structure. Each of the different situations analized will be exhaustively explained in the following sections.

PRELIMINARY CALCULATIONS

The model used in this section and also throughout this work with only very small additional considerations is a box girder which cross section is pictured in figure 1.

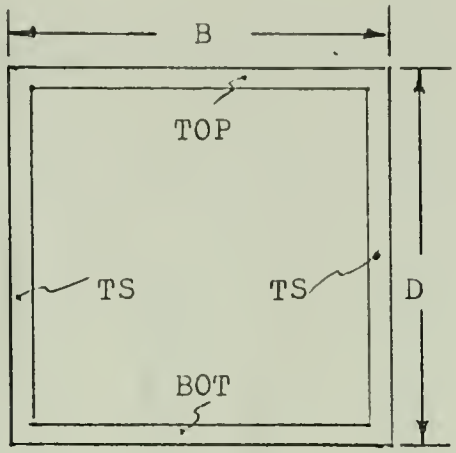


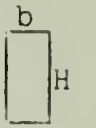
Fig. 1

As will be seen in the calculations of the following sections, the dimensional parameters used are of the order of magnitude of those considered in ship design.

This model was chosen due to its simplicity for the performance of the following calculations as can be understood immediately from its geometrically symmetrical cross section.

The objective of this section is to determine the necessary formulation to be used in future sections.

The formulation dealt with in this section is related only to the particular model chosen and the geometry of its cross section.

MEMBER	SCANTLINGS inches (in)	AREA A $(in)^2$	DISTANCE TO BOTTOM (ft)	A*d $(in*ft)^2$	A*d*d $(in*ft)^2$	WIDTH of member b(in)	HEIGHT OF MEMBER H(ft)	 $I=b*H^3$ $(in*ft)^2$
TOP	B*TOP	B*TOP	D/12	B*TOP*D/12	B*TOP*(D/12)^2	B	-	-
SIDE	2*TS*D	2*TS*D	D/(2*12)	TS*D*D/12	TS*D*(D/12)^2/12	2*TS	D/12	2*TS*(D/12)^3
BOTTOM	B*BOT	B*BOT	-	-	-	b	-	-
		Σ A=		Σ(A*d)=	Σ(A*d*d)=			Σ I=

$+ \quad \Sigma I =$

$I_{BOT} =$

$-\Sigma A*(DIBOT')^2 =$

$$DIBOT = \frac{\Sigma(A*d)}{\Sigma A} * 12$$

$$DIBOT' = \frac{\Sigma(A*d)}{\Sigma A}$$

$$\Sigma A = B*TOP + 2*TS*D + B*BOT = 2*D*TS + B*(TOP+BOT)$$

DIBOT =Neutral axis location above bottom (in)

DIBOT'= " " " " " (ft)

I_{BOT} =Moment of inertia with respect to the bottom

I = " " " " " " " neutral axis

$$\Sigma(A*d) = (D/12)*(B*TOP+D*TS)$$

$$I = \Sigma(A*d*d) + \Sigma I - (\Sigma(A*d))^2/(\Sigma A)$$

DIBOT=D*(B*TOP+D*TS)/(2*D*TS+B*(TOP+BOT))

This formula will give DIBOT in inches if D and B are expressed in inches; it will give DIBOT in feet in the event that D and B are expressed in feet.

DITOP=D-DIBOT

DITOP=D*(B*BOT+D*TS)/(2*D*TS+B(TOP+BOT))

DITOP in units of inches or feet as explained for DIBOT

The following formula will give I in units of $(in*ft)^2$ for B and D given in inches.

$$I=\frac{(D/12)^2*(3*B*B*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT))}{3*(2*D*TS+B*(TOP+BOT))}$$

Next formula gives I in units of $(in*ft)^2$ for B and D given in feet.

$$I=\frac{4*D*D*(3*B^2*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT))}{2*D*TS+B*(TOP+BOT)}$$

These expressions will be used in most of the following sections with B and D expressed in feet.

NOTE: TS which is defined as the thickness of the side plating is considered throughout this work to be uniform and will always be equal to the larger of the thicknesses obtained for the top and for the bottom plating.

FORMULAS USED IN THE ANALYSIS

BEAM EQUATION

Assuming pure bending, the stresses in the cross section of the box girder are given by

$$STR = \frac{BM * y}{I}$$

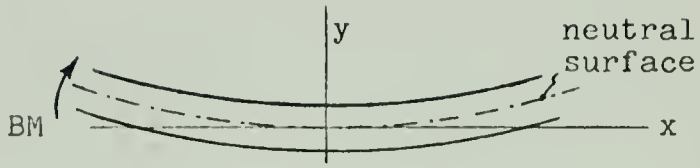


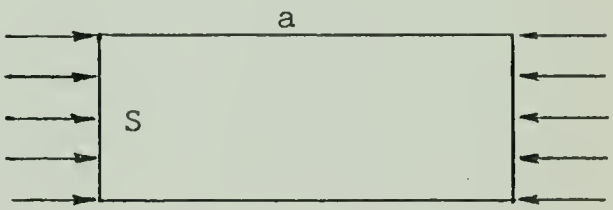
Fig. 2

where y is the distance from the neutral axis to the point where the stress is being determined.

The neutral surface indicated in fig. 2 is composed of all the points which are not subjected to any stress in pure bending.

BRYAN EQUATION - Plate under inplane load

$$STRCR = K * \frac{(\pi)^2 * E * (t)^2}{12 * (1-(POI)^2) * (S)^2}$$



When $a/S > 2$ then $K = 4$

STRCR given in psi for t andS expressed in inches and E in psi.

$\pi = 3.1416$

PLATE UNDER LATERAL LOAD

$$STR3=0.5*K*\rho*H*\left(\frac{S}{t}\right)^2*\frac{1}{144}$$

STR3 - tertiary stress

ρ - density of sea water (64 lb/ft^3)

H - head of sea water (ft)

a - long dimension of plate (in)

S - short dimension of plate (in) = distance between longitudinal stiffeners

t - plate thickness (in)

The stresses are more severe at points A and B but we are particularly interested in the stresses at point B because there they will combine with the stresses resulting from bending also called primary stresses.

Note that for a panel under lateral load, the direction of the stresses is, at the edges, perpendicular to them, so at B they are directed "longitudinally".

For $a/S>2$ we have $K=0.685$

Replacing all the numbers in the above formula, we obtain

$$STR3=0.152222*H*\left(\frac{S}{t}\right)^2$$

BENDING STRESSES IN FLAT PLATES

WITH CLAMPED EDGES UNDER UNIFORM HYDROSTATIC LOAD

σ = Bending stress (lbs/sq in)

ρ = Density of sea water (64 lbs/cu ft)

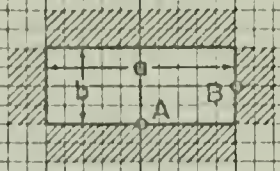
H = Head of sea water (feet)

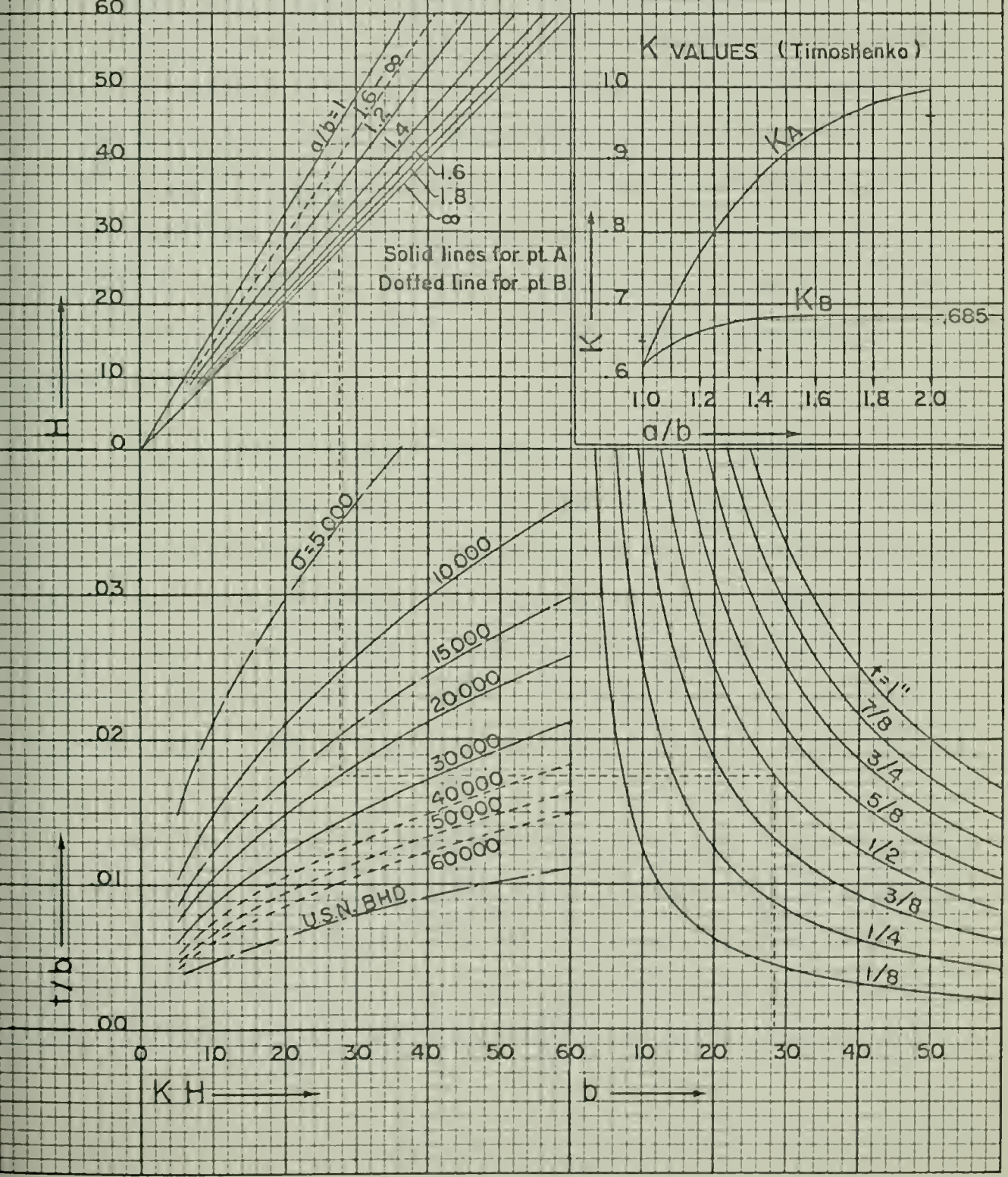
a = Long dimension of plate panel (inches)

b = Short dimension of plate panel (inches)

t = Plate thickness (inches)

Formula: $\sigma = \frac{1}{2} K \rho H \left(\frac{b}{t}\right)^2 \frac{1}{144}$





The following stress definitions and figures 3 and 4 will help understanding the reasons behind the calculations made in many of the following sections.

STRESS DEFINITIONS

STR1 - SHIP BENDING STRESS or PRIMARY STRESS

Since this stress is directly proportional to distance from the ship's neutral axis, it is substantially constant at any point on the cross section of the bottom or top plating when the vessel is in an upright attitude. For distinction, this stress may be termed a primary stress or an area stress in this location and under such a condition. While the longitudinal direction is implied in the foregoing comments, they are equally applicable transversely.

STR2 - GIRDER BENDING STRESS or SECONDARY STRESS

Girder bending stress arises from the reaction of a plating stiffener combination to a loading normal to the plating such as may be due to water pressure. Following the usual concept, the plating acts as one flange of the composite girder and so is stressed. Due to shear lag, this secondary stress in the plating is a maximum in way of the stiffener and diminishes with distance from it.

For the previous case of bottom plating and vessel upright, the transverse variation of fore and aft stress will be sensibly constant for some distance from the stiffener but will vary significantly through the plating thickness as the plate thickness is a substantial part of the distance to the neutral axis

of the plate stiffener combination. For convenience such a stress may be termed a line stress although for a wide spacing of stiffeners with consequently greater deviation from uniform distribution some inaccuracy of concept is introduced by using this term.

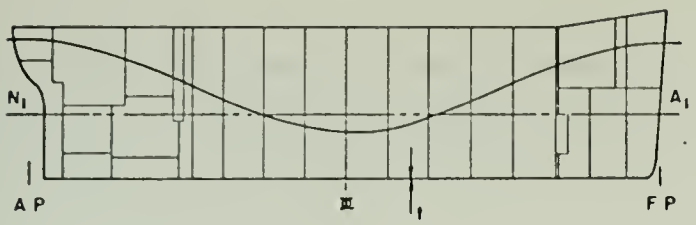
For girders continuous over several supports, such as transverse bulkheads, maximum bending moments occur at the supports and will readily be in the order of twice the field moment.

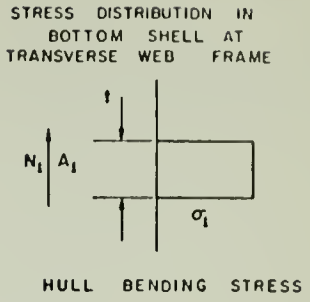
STR3 - PLATE BENDING STRESS - TERTIARY STRESS

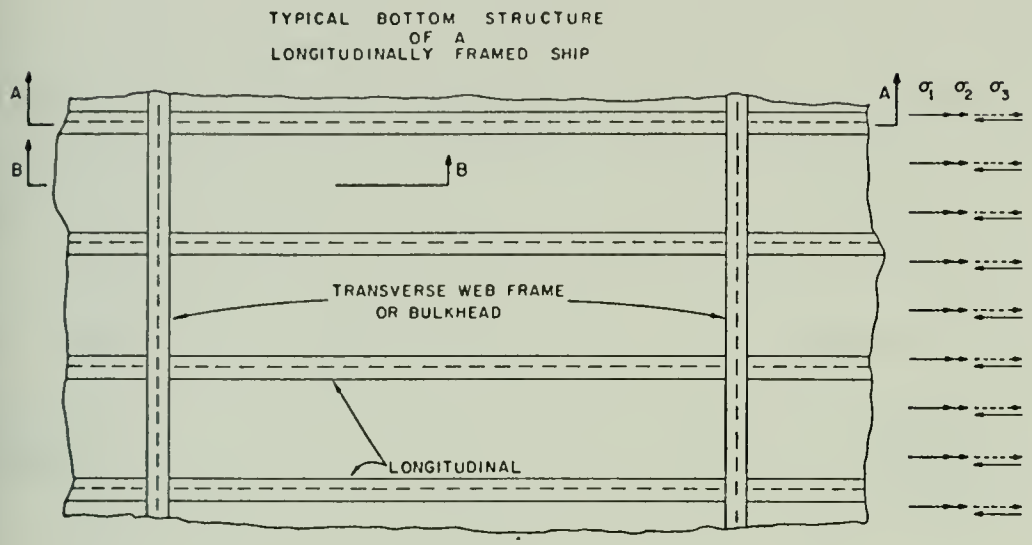
Proceeding in turn to ever more elemental portions of the ship's structure concludes with the simple plate panel supported on its four edges. In such a plate under lateral or normal loads, bending stresses are created which are variable from point to point on the panel and through its thickness with maxima occurring at one or the other surface. Since any such stress is effective at a point only, it may be called a point stress or tertiary stress.

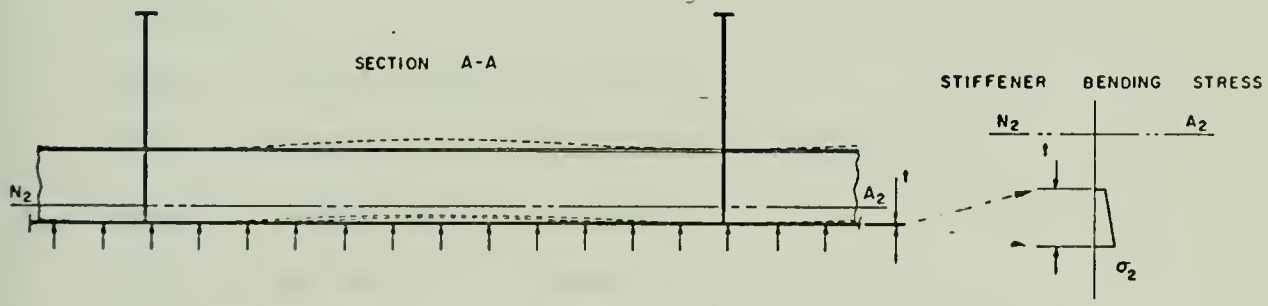
Each elemental panel of ship's plating is generally one of a repeating pattern. Quite appart from any rotational restraint provided by the panel supports consisting of floors, frames, longitudinals, etc., there is the restraint afforded by the continuity of the plating and its loading. For pratical purposes then, a condition of edge clamping exists with maximum stresses being found at the midlength of the longer panel edges and secondary maxima at the midlength of the shorter edges. In both cases these stresses are normal to their respective edges.

BENDING STRESSES IN SHIPS









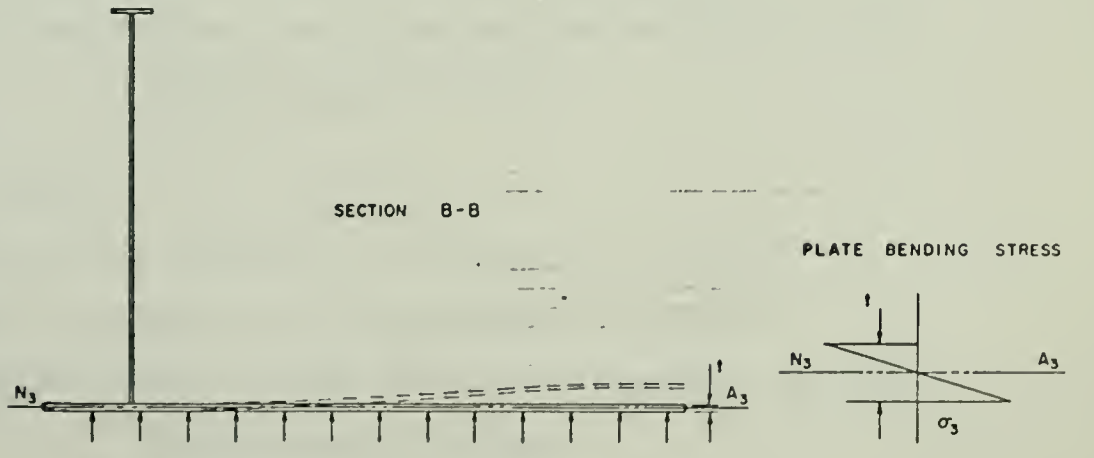


FIGURE 3

From the previous definitions and figure 3 we may summarize in figure 4 the effect of STR1, STR2 and STR3.

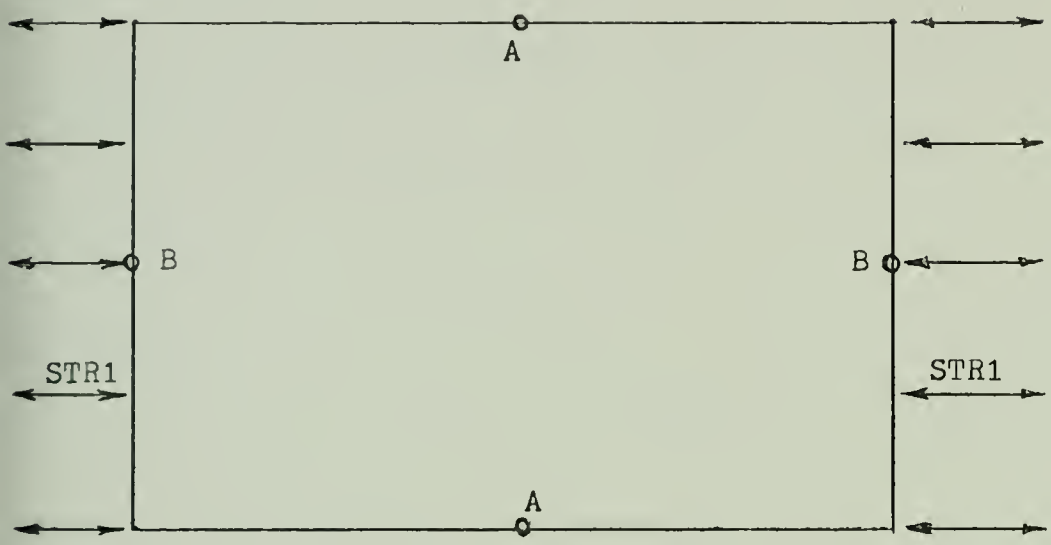


Fig. 4

At point A

STR2 is larger than at point B

STR2 is acting in the longitudinal direction

STR3 is larger than at point B

STR3 is acting in the transverse direction

STR1 and STR2 are here combined acting both in the longitudinal direction

At point B

STR2 may be acting in the tansverse direction

STR3 is acting in the longitudinal direction

STR1 and STR3 are here combined acting both in the longitudinal direction.

Usually STR2 is attributed a constant value and can be taken into account by automatically decreasing the design stress by the value assigned to STR2.

THE BENDING MOMENT EQUATION

The bending moment equation used is derived from

$$BM = \Delta * AL/35 \qquad ton*ft$$

knowing that

$$\Delta = \nabla/35 \qquad ton$$

and that

$$\nabla = B*T*AL*C_b$$

and using

$$C_b = 0.75$$

we obtain

$$BM = \frac{0.75}{35*35} *B*T*AL*AL \qquad ton*ft$$

where AL = is the length in ft

B = is the beam in ft

T = is the draft in ft

C_b = is the block coefficient

or multiplying by 2240 we obtain

$$BM = 1.37143*B*T*AL*AL \qquad lb*ft$$

Note:

∇ is the displacement volume and Δ is the corresponding displacement weight.

MOMENT ACTING IN ONE DIRECTION

NO RESTRICTION IMPOSED ON THE COMPRESSION STRESS

Considering the box girder subjected to a bending moment acting in hogging BM, we will observe as a consequence that the top will be subjected to tension and the bottom to compression. These stresses are given by the already introduced formula

$$STR = \frac{BM*Y}{I}$$

or in this case, being interested on the top and bottom,

$$STH = \frac{BM*DIBTOP}{I}$$

$$SBH = \frac{BM*DIBOT}{I}$$

In this introductory study it was decided not to limit the value of the stress in compression. Only the value of the stress in tension, here STH will be requested to be equal to the value chosen for the design stress in tension (or smaller).

SBH will be a consequence of the value of DST and also of the S value chosen.

So, we will basically have 3 equations

DST = STH↔TOP Bending equation

S ↔ SBH ↔ BOT Bending equation + Bryan formula

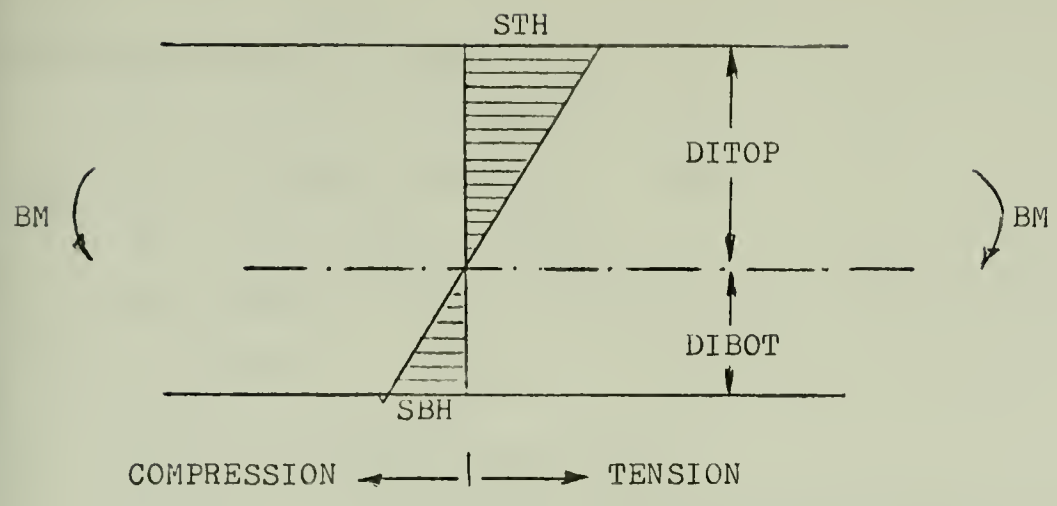


Fig. 5

The three equations that can be obtained will allow one to determine the three unknowns which are BOT,SBH,TOP.

By replacing in the equations already mentioned the expressions derived previously for DIBOT, DITOP and I and solving for BOT,TOP and SBH we obtain after a lengthy but simple process the equations in their final format as we will see.

Note here that in order to solve the three equations, the thickness of the side plates TS was made equal to the larger TOP or BOT; since TOP and BOT were not known and had to be determined after deciding on TS, the equations had to be solved twice. First the equations are solved assuming that TOP > BOT this simply implying that the neutral axis is going to be chosen already closer to the top and TS = TOP. Second, the equations are solved assuming BOT > TOP thus making TS = BOT.

As will be seen, only one solution is possible, the other being rejected by giving a result that does not agreee with the

assumption just mentioned.

TOP , BOT , S (inches)

B , D , DITOP , DIBOT , AL (ft)

DST , STH , SBH , E (psi)

BM (ton*ft)

I $(in*ft)^2$

$$DST \geq STH = \frac{560*BM*(B*BOT+D*TS)}{D*(3*B*B*TOP*BOT+2*B*D*TS*(TOP+BOT)=(D*TS)^2)}$$

$$SBH = \frac{560*BM*(B*TOP+D*TS)}{\text{Same denominator}}$$

$$BOT = \sqrt{G}\ \sqrt{SBH}$$

$$G = 0.30396*\frac{(S)^2*(1-(POI)^2)}{E}$$

$$\frac{DST}{SBH} = \frac{B*BOT+D*TS}{B*TOP+D*TS}$$

Making

$$A = \frac{9*B*B*D}{140*BM}$$

$$C = \frac{3*B*D*D}{70*BM}$$

$$F = \frac{3*D*D*D}{140*BM}$$

we will obtain, by assuming first TOP > BOT

$$DIBOT = \frac{D*(B+D)*TOP}{(2*D+B)*TOP+B*BOT}$$

$$DITOP = \frac{D*(B*BOT+D*TOP)}{\text{Same denominator}}$$

$$I = 4*D*D*\frac{(2*B*D+D*D)*TOP*TOP+(2*B*D+3*B*B)*TOP*BOT}{\text{Same denominator}}$$

$$TOP = \frac{B*(BOT)^3}{(B+D)*G*DST-D*(BOT)^2}$$

$$BOT = \frac{TOP*(12*D-(C+F)*DST*TOP)}{DST*(A+C)*TOP-12*B}$$

Before going to the equations obtained when BOT > TOP is assumed, we call the attention of the reader to the fact that the values of BOT and TOP have to be obtained from the two above equations. Substitution of one into the other would result in an equation of degree higher than at least 5^{th} degree, unsuitable for direct solution. As will be later exemplified, the solution is here obtained by assigning values to either one of BOT and TOP and through the two equations, we obtain the respective values for TOP and BOT. The ploting of these values BOT vs TOP will give one line for each of the two equations. The intersection of the two lines thus obtained allows the solution to be read from the plot.

This solution will be acceptable if the intersection lies in the sector TOP > BOT otherwise the intersection must be rejected.

Assuming now BOT > TOP we make TS = BOT and obtain:

$$DIBOT = \frac{D*(B*TOP+D*BOT)}{(2*D+B)*BOT+B*TOP}$$

$$DITOP = \frac{D*(B+D)*BOT}{\text{Same denominator}}$$

$$I = 4*D*D*\frac{(2*B*D+D*D)*(BOT)^2+(2*B*D+3*B*B)*TOP*BOT}{\text{Same denominator}}$$

$$TOP = \frac{(B+D)*(BOT)^3-D*G*DST*BOT}{B*G*DST}$$

$$BOT = \frac{12*(B+D)-(A+C)*DST*TOP}{(C+F)*DST}$$

In this form the equations can be used in a very simple computer program that will give the set of values TOP vs BOT suitable for ploting. At this stage we are hoping that if the intersection obtained in the situation where we assumed TOP > BOT is acceptable, the two lines resulting from the case BOT > TOP will not intersect or if they do that the intersection must be rejected due to the fact that they will violate the assumption from which they were derived

As can be observed from the several cases run in the computer, the case where two acceptable solutions exist never happened and it can only happen if TOP = BOT where then both solutions are acceptable and coincide as in the case of one of the following runs.

In the following pages the computer printouts are included. The first run is explained in detail to make the interested reader familiar with the problems encountered in determining the intersections and the respective thicknesses.

The other runs are here presented as well to serve as proof that a simple solution can always be obtained and also to give an idea of the range of thicknesses expected in each case.

In all runs only a bending moment acting in hogging was considered.

The program used is a direct application of the equations here derived to a particular set of values chosen as the input. From the results obtained, some conclusions were drawn that allowed for the improvements made in following sections.

No further explanation on the program shall here be given because it is self explanatory in the comment statements included.

```
2014     C      *AL* IS THE LENGHT
2?14            AL=5??.
2?7C            B=AL/8.
2?18     C      *DRA* IS THE DRAFT
2?18            DRA=B/3.
2?2?            D=AL/9.
2?3?     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
2?3?     C      FOR STEEL
2?3?            POI=?.3
2?3?     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
2?3?     C      FOR STEEL
2?3?            E=3?.*1?.**6
2?4C     C      *DST* IS THE DESIGN STRESS
2?4C            DST=2?????.
2?5?     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
2?5?            S=1?.
2?6C     C      *BM* IS THE BENDING MOMENT
2?7C            BM=(B*DRA*AL*AL*?.75)/(35.*35.)
2?8?            C=?.3?396*S*S*(1.-POI*POI)/E
2?9?            A=?.**?**B*D/(14?.*BM)
2?AC            C=3.**?**D*D/(?8.*BM)
2?B?            E=?.**D**D*D/(14.**BM)
2?2C     C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
2?2C            WRITE(5,17)
2?42        17  FORMAT('1',2?X,'TOP ASSUMED LARGER THAN BOTTOM')
2?6?     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
2?6?     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
2?6?            BOT1=?.1
2?7A        11  TOP1=?**BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
2?BE            WRITE(5,2?)TOP1,BOT1
2?E?        2?  FORMAT(' ',25X,'TOP1='F?.4,5X,'BOT1='F9.4)
2??1            BOT1=BOT1+?.?25
2?1A            IF(BOT1.GT.?.2)GO TO 3?
2?2?            GO TO 11
2?2C        3?  TOP2=?.1
2?34        31  BOT2=TOP2*(12.*D-(C+E)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
2?4?            WRITE(5,4?)TOP2,BOT2
2?5A        4?  FORMAT(' ',25X,'TOP2='F?.4,5X,'BOT2='F9.4)
2?6C            TOP2=TOP2+?.?5
2?F?            IF(TOP2.GT.1.)GO TO 5?
2?FA            GO TO 31
2?FE        5?  CONTINUE
2?FE     C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
2?FE            WRITE(5,6?)
2319        6?  FORMAT('1',2?X,'BOTTOM ASSUMED LARGER THAN TOP')
2340            BOT3=?.1
2348        61  TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
2394            WRITE(5,7?)TOP3,BOT3
23A8        7?  FORMAT(' ',25X,'TOP3='F?.4,5X,'BOT3='F9.4)
23E?            BOT3=BOT3+?.?5
23EC            IF(BOT3.GT.1.)GO TO 8?
23FE            GO TO 61
```

```
0402        80 TOP4=0.1
040A        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
044E           WRITE(5,90)TOP4,BOT4
0472        90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
049A           TOP4=TOP4+0.5
04A6           IF(TOP4.GT.1.)GO TO 100
04B8           GO TO 81
04BC       100 CONTINUE
04BC           END
0000(S) .U      04C0(V) AL      04C8(V) B       04D0(V) DRA     04D8(V) D
04E0(V) POI     04E8(V) E       0000(S) .R      04F8(V) DST     0500(V) S
0518(V) BM      0518(V) G       0524(V) A       052C(V) C       0534(V) F
0000(L) 10      0000(S) @I      0538(V) BOT1    0176(L) 11      0540(V) TOP1
0022(L) 22      0022(L) 30      0554(V) TOP2    0234(L) 31      0552(V) BOT2
0040(L) 40      02FF(L) 50      0312(L) 60      056C(V) BOT3    0348(L) 61
0388(V) TOP3    0388(L) 70      0402(L) 80      0574(V) TOP4    040A(L) 81
0472(L) 90      048C(L) 100     0000(S) .V
. XEQ          L
:OF


PROGRAM LABELS:
  2070 *MAIN*    2C0C .V        2A3C .COMP     2C1A @I        25EC .R        2B04 .ZE
  2A62 $6        262C .A        2B60 .MES      29DE .W        27E6 EXP       296C AI
  26DE ALOG      2AA4 .RARG     2B02 .5        27F6 AEXP      2B08 .ERCNT    2AD6 $8
  2B0A .O        2B0E .U        3D36

ENTRY-POINTS:
  25EC .R        262C .A        26DE ALOG      27E6 AEXP      27E6 EXP       296C AI
  29DE .W        2A3C .COMP     2AE2 $6        2AA4 .RARG     2AD6 $8        2B00 .5
  2B04 .ZERO     2B08 .ERCNT    2B0A .O        2B60 .MES      2BEA .U        2C10 .V
  2C1A @I


COMMON-BLOCKS:
NONE


UNDEFINED SUBROUTINES:
NONE


TRANSFER ADDRESS 2070
EXECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0385	BOT1=	0.1000
TOP1=	0.0462	BOT1=	0.1050
TOP1=	0.0553	BOT1=	0.1100
TOP1=	0.0659	BOT1=	0.1150
TOP1=	0.0784	BOT1=	0.1200
TOP1=	0.0933	BOT1=	0.1250
TOP1=	0.1109	BOT1=	0.1300
TOP1=	0.1321	BOT1=	0.1350
TOP1=	0.1576	BOT1=	0.1400
TOP1=	0.1889	BOT1=	0.1450
TOP1=	0.2276	BOT1=	0.1500
TOP1=	0.2763	BOT1=	0.1550
TOP1=	0.3392	BOT1=	0.1600
TOP1=	0.4225	BOT1=	0.1650
TOP1=	0.5374	BOT1=	0.1700
TOP1=	0.7043	BOT1=	0.1750
TOP1=	0.9669	BOT1=	0.1800
TOP1=	1.4359	BOT1=	0.1850
TOP1=	2.5007	BOT1=	0.1900
TOP1=	7.1867	BOT1=	0.1950
TOP1=	-11.0527	BOT1=	0.2000
TOP2=	0.1000	BOT2=	-0.1738
TOP2=	0.1500	BOT2=	-0.1758
TOP2=	0.2000	BOT2=	-0.2808
TOP2=	0.2500	BOT2=	-0.4765
TOP2=	0.3000	BOT2=	-1.1361
TOP2=	0.3500	BOT2=	2.8493
TOP2=	0.4000	BOT2=	0.5282
TOP2=	0.4500	BOT2=	0.2263
TOP2=	0.5000	BOT2=	0.1025
TOP2=	0.5500	BOT2=	0.0287
TOP2=	0.6000	BOT2=	-0.0534
TOP2=	0.6500	BOT2=	-0.1244
TOP2=	0.7000	BOT2=	-0.1487
TOP2=	0.7500	BOT2=	-0.1888
TOP2=	0.8000	BOT2=	-0.2260
TOP2=	0.8500	BOT2=	-0.2612
TOP2=	0.9000	BOT2=	-0.2950
TOP2=	0.9500	BOT2=	-0.3276
TOP2=	1.0000	BOT2=	-0.3593

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	0.7135	BOT3=	0.1000
TOP3=	0.2124	BOT3=	0.1500
TOP3=	0.6417	BOT3=	0.2000
TOP3=	1.3783	BOT3=	0.2500
TOP3=	2.4990	BOT3=	0.3000
TOP3=	4.0807	BOT3=	0.3500
TOP3=	6.2001	BOT3=	0.4000
TOP3=	8.9341	BOT3=	0.4500
TOP3=	12.3596	BOT3=	0.5000
TOP3=	16.5533	BOT3=	0.5500
TOP3=	21.5920	BOT3=	0.6000
TOP3=	27.5527	BOT3=	0.6500
TOP3=	34.5121	BOT3=	0.7000
TOP3=	42.5470	BOT3=	0.7500
TOP3=	51.7342	BOT3=	0.8000
TOP3=	62.1507	BOT3=	0.8500
TOP3=	73.8731	BOT3=	0.9000
TOP3=	86.9784	BOT3=	0.9500
TOP3=	101.5434	BOT3=	1.0000
TOP4=	0.1000	BOT4=	0.0961
TOP4=	0.1500	BOT4=	0.0931
TOP4=	0.2000	BOT4=	0.0101
TOP4=	0.2500	BOT4=	0.7170
TOP4=	0.3000	BOT4=	0.6240
TOP4=	0.3500	BOT4=	0.5310
TOP4=	0.4000	BOT4=	0.4379
TOP4=	0.4500	BOT4=	0.3449
TOP4=	0.5000	BOT4=	0.2519
TOP4=	0.5500	BOT4=	0.1589
TOP4=	0.6000	BOT4=	0.0658
TOP4=	0.6500	BOT4=	-0.0272
TOP4=	0.7000	BOT4=	-0.1202
TOP4=	0.7500	BOT4=	-0.2133
TOP4=	0.8000	BOT4=	-0.3 63
TOP4=	0.8500	BOT4=	-0.3993
TOP4=	0.9000	BOT4=	-0.4923
TOP4=	0.9500	BOT4=	-0.5854
TOP4=	1.0000	BOT4=	-0.6784

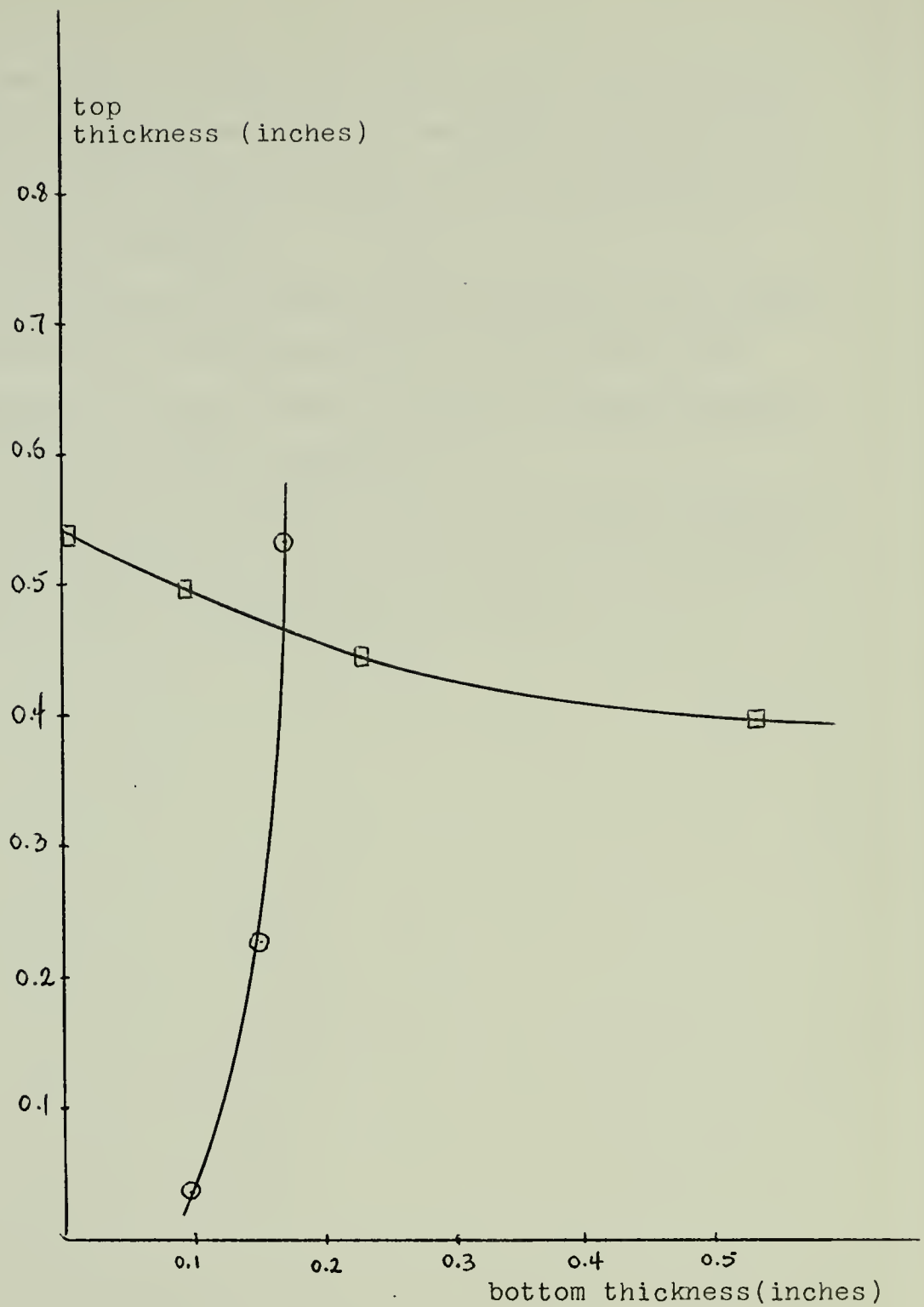
END

CF VIC OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74

JOB HANDLING CHARGE	$ .35 / JOB		.35
175 LINES PRINTED PR2	$ 1.25 / K LN		.22
67 CARDS READ	$ 1.50 / K CD		.10
00 PLOTTER VECTORS	$ .25 / 1000		.00
15 MODEL 70 SECONDS	$25.00 / HOUR		.10
00 MODEL 80 SECONDS	$12.50 / HOUR		.00
	TOTAL CHARGE $		.77

PREIR 490 14731 LOGGED OUT 05/06/74 15:14. $ 14.10 LEFT AFTER 17 LOGINS.

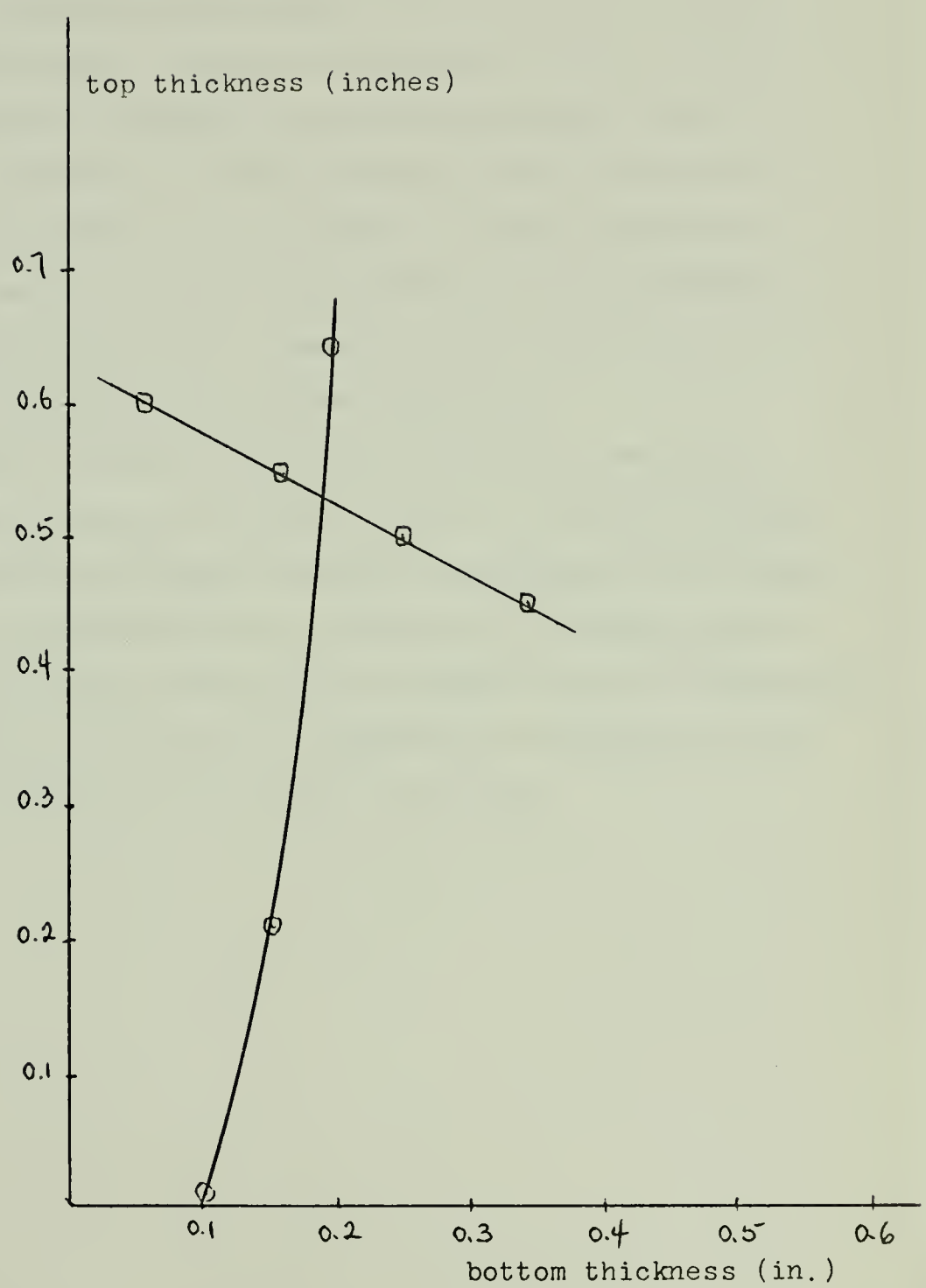
From these lists of thickness values printed by the computer, we can see that the acceptable ones are those marked with a ‖ sign. Plotting these corresponding pairs of values properly, as is next exemplified, allows for one to read from the intersection of the two lines, which falls within the range set by the assumption that originated it, the values of thicknesses at the top and at the bottom which satisfy the model we started with.


top
thickness (inches)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
bottom thickness(inches)

We can see that the thickness values are easily read from the intersection obtained and they are acceptable because they fall within the range assumed to derive the formulas that originated them namely TOP > BOT.

Next will be plotted the case BOT > TOP and as can be seen, again an intersection is obtained which in this case is not acceptable because it occurs within the range TOP > BOT contrary to the assumed BOT > TOP that originated it.

With a little more experience, this can be seen immediatly from the computer printouts, thus avoiding loss of time doing a plot that will lead to a nonacceptable result.


top thickness (inches)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

Now having obtained the values for the thicknesses from the plots, we verify them through the use of the next program based on the formulation previously derived. As can be noted, we obtain an acceptable value for the stress at the top (since we are considering a hogging bending moment) which we said before in the derivation of the equations should not exceed the design stress in tension. In this case the design stress was DST=20000 psi and we see that the stress at the top STH=20037.5 the 37.5 coming possibly from inaccuracy when reading the thicknesses from the plot, and computer roundoffs.

Note that the stress at the bottom, since there was no limit placed on it except the Bryan formula to resist buckling caused by compressive inplane loading, is attaining a too large value which is unacceptable and unrealistic. Here again there should be no difference between SBH and SBCRIT and the difference that can be noted is also due to inaccuracy in reading the thicknesses from the plot and computer round-offs.

```
0 04      C       *AL* IS THE LENGTH
0 04              AL=SL*.
0 07              E=AL/S.
0 1       C       *DR* IS THE DRAFT
0 1               DR=.
0 2               R=AL/S.
0 3       C       *P0* IS THE POISSON'S RATIO OF THE MATERIAL
0 3       C       FOR STEEL
0 3               P0I=.3
0 3       C       *W* IS THE UNIT WEIGHT OF THE MATERIAL
0 3       C       FOR STEEL
0 3               C=3.*1 ***
0 4       C       *FST* IS THE DESIGN STRESS
0 4               FST=
0 5       C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0 5               S=1
0 5       C       *TP* IS THE PLATING THICKNESS
0 5               TP=( *(L*AL .*3))/(2 .*35.)
0 6               T=.*S*(.+F*I)/F
0 6       C       *TOP* IS THE THICKNESS OF THE TOP PLATING
0 6       C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0 6               TOP= .4F
0 7               BOT= .1
0 C               A=S .**.*(.*BOT+.*TOP)
0 F               IE= *(.*.**.*T**3+BOT*.2**3+.0*TOP*(TOP+BOT)+(D*(*TOP*TOP)))
0140      C       *STR* IS THE STRESS AT TOP DUE TO BENDING
0140              STR=*/I
0155              WRITE(3,4*)STR
0174          4   FORMAT(' ',2X,'STR='E1 .3)
0154              C=5 .**.*(.*TOP+.*T.D)
015A      C       *SB* IS THE STRESS AT BOT DUE TO BENDING
0164              SB=C/I
0170              WRITE(3,5.)SB
0172          5   FORMAT(' ',2X,'SB='E1 .3)
017C      C       *SCRIT* IS THE CRITICAL STRESS ON BOT
017C              SCRIT=.*T*.0T*/
0220              WRITE(3,11 )SCRIT
0225         11   FORMAT(' ',1X,'SCRIT='F1 .3)
0244              D=2.*.*I*.3*(T*T+T
0249      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
0269              DITOP=*(.*BOT+.*TOP)/I
0230              WRITE(3,4 )DITOP
0245          4   FORMAT(' ',1X,'DITOP='F1 .4)
0254      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0254              DIBOT=*(.*TOP+ .*TOP)/I
0265              WRITE(3,4 )DIBOT
0274          4   FORMAT(' ',1X,'DIBOT'=F1 .4)
027C              STOP
0300 [S] ..       0324[V] AL        0330[V] BOT       0334[V] DR        033C[V] D
0344[V] DT        034C[V] E         0354[V] I         035C[V] DST       0364[V] S
036C[V] ...       0374[V] T         037C[V] TOP       0384[V] BOT       038C[V] A
0394[V] DIB       039C[V] STR       03A4[V] SB        03AC[S] WT        03BC[V] C
```

```
    STAT CNT CE SEIGMENT [ENTRY] SYM LOCATION                    PAGE   2

RC [V] [illegible]  IFS [L] [illegible]  RCA [V] SCRIPT  CP [L] 11  RSC [V] P
BC [V] [illegible]  PAS [L] 40  [illegible] SYM [T]  [illegible] [L] 50  RCA [S] .V
[illegible]  L
[illegible]


PROGRAM ENTRIES:
  2270 [illegible]  2444 .R  [illegible]  2272  T  2444 .R  2450 .Z
  22BA [illegible]  [illegible]  [illegible]  2438  .  2691 EXP  27C4 AT
  2538 [illegible]  [illegible]  [illegible]  2438 .EXP  2969 .ERCLT  2A2E SS
  2AA0 .S  [illegible]  [illegible]


ENTRY-POINTS:
  2444 .R  [illegible]  [illegible]  2438 .EXP  2438 EXP  27C4 AT
  2438 .  [illegible]  [illegible]  2BEC .ASCII  2921 ES  2A18 .
  2BEC .ASCII  [illegible]  [illegible]  2AA9 .TES  2A42 .U  2A68 .
  2A72 .T


[illegible]:
[illegible]


[illegible]:
C F


RESET = [illegible] 2070
ECLIPSE [illegible] TIMES:

                    STM= [illegible]
                    SAM= [illegible]
                 SECTIE= [illegible]
                  CLOCK=   [illegible]
                  CYCLE=   [illegible]

END


CP/V/IO OPERATING SYSTEM  VERSION [illegible] REVISION  12  3/14/74 GENERATED  5/16/74


[illegible] HANDLING CHARGE  1 [illegible]  .3
85 LINES [illegible]  1 1.25 / 4 [illegible]  .1
54 CARDS READ  1 1.50 / [illegible]  .2
20 PLOTTER VECTORS  1 [illegible]  .0
13 MODEL 44 SECONDS  .25 / [illegible]  .3
21 MODEL 44 SECONDS  .25 / [illegible]  .3
                    TOTAL CHARGE  .6


R-SIP 407 14731  LOGGED OUT 05/24/74 15:43.  6  11.7M LEFT AFTER  2M LOGINS.
```

SUMMARY FOR THE PRECEDING CASE

Length	= 500 ft
Beam	= AL/8
Draft	= B/3
Depth	= AL/9
DST	= 20000 psi
S	= 10 inches
Material	- STEEL
TOP	= 0.468 inches
BOT	= 0.166 inches
STH	= 20037.45
SBH	= 30434.89
SBCRIT	= 29886.80
DITOP	= 22.06 ft
DIBOT	= 33.50 ft

We can already notice here that the stress in the bottom is attaining a too large value due to the fact that, since no limit was imposed on it, it is dependent only on the chosen value for S and the respective capacity to resist buckling provided by S and BOT while at the same time stressing the top plate to its maximum allowed DST.

In the following two cases only the spacing S between the longitudinal stiffening members will be allowed to change and the results obtained are simply stated as previously exemplified and were determined in a similar way.

From the results obtained we can note the effect caused by the change of S.

```
0024     C      *AL* IS THE LENGHT
0024            AL=500.
002C            B=AL/8.
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.
0024            D=AL/9.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR STEEL
0030            POI=0.3
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR STEEL
0038            E=30.*10.**6
004C     C      *DST* IS THE DESIGN STRESS
004C            DST=20000.
0054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0054            S=30.
005C     C      *BM* IS THE BENDING MOMENT
005C            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
0068            G=0.300396*S*S*(1.-POI*POI)/E
0076            A=9.*B*B*D/(140.*BM)
007C            C=3.*B*D*D/(70.*BM)
0086            F=3.*D*D*D/(140.*BM)
0120     C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
0120            WRITE(5,10)
0140        10  FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
0160     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
0160     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0160            BOT1=0.1
0174        11  TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
018E            WRITE(5,20)TOP1,BOT1
01B0        20  FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
01D2            BOT1=BOT1+0.05
01E6            IF(BOT1.GT.1.)GO TO 30
01E8            GO TO 11
01EC        30  TOP2=0.1
01F4        31  BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
0200            WRITE(5,40)TOP2,BOT2
0214        40  FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
022C            TOP2=TOP2+0.05
0240            IF(TOP2.GT.1.)GO TO 50
0244            GO TO 31
024E        50  CONTINUE
024E     C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
024E            WRITE(5,60)
0272        60  FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
0290            BOT3=0.1
0298        61  TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
02B4            WRITE(5,70)TOP3,BOT3
02B8        70  FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
02E0            BOT3=BOT3+0.05
02EC            IF(BOT3.GT.1.)GO TO 80
02EE            GO TO 61
```

```
2482        80 TOP4=0.1
248A        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
249E           WRITE(5,90)TOP4,BOT4
24B2        90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
24CA           TOP4=TOP4+0.05
24D6           IF(TOP4.GT.1.)GO TO 100
24E8           GO TO 81
24EC       100 CONTINUE
24EC           END
```

```
0000[S] .U        04C0[V] AL        04C8[V] B         04D0[V] DRA       04D8[V] D
04E0[V] POI       04E8[V] E         0000[S] .F        04F8[V] DST       0500[V] S
0518[V] BM        0518[V] G         0524[V] A         052C[V] C         0534[V] F
0000[S] 12        0000[S] @I        0538[V] BOT1      0176[L] 11        0542[V] TOP1
0220[L] 22        0220[L] 30        0550[V] TOP2      0234[L] 31        0554[V] BOT2
02FF[L] 40        02FF[L] 50        0312[L] 62        0564[V] BOT3      0348[L] 61
03B8[L] 70        03B8[L] 80        0402[L] 82        056C[V] TOP4      040A[L] 81
0472[L] 90        0472[L] 90        04BC[L] 100       0000[S] .V
. XEQ          L
OF
```

```
ROGRAM LABELS:
 2070 *MAIN*     2CC4 .V         2A34 .COMP      2C12 @I         25E4 .R         2AFC .ZF
 2A54 $6         2624 .A         2B58 .MES       29D6 .W         27DE EXP        2964 AIN
 26D6 ALOG       2A9C .RARG      2AF8 .5         27DE AEXP       2B00 .ERCNT     2ACE $8
 2B22 .O         2BD6 .U         3D2E

NTRY-POINTS:
 25E4 .R         2624 .A         26D6 ALOG       27DE AEXP       27DE EXP        2964 AIN
 29D6 .W         2A34 .COMP      2A5A $6         2A9C .RARG      2ACE $8         2AF8 .5
 2AFC .ZERO      2B00 .ERCNT     2B22 .O         2B58 .MES       2BE2 .U         2CC8 .V
 2C12 @I

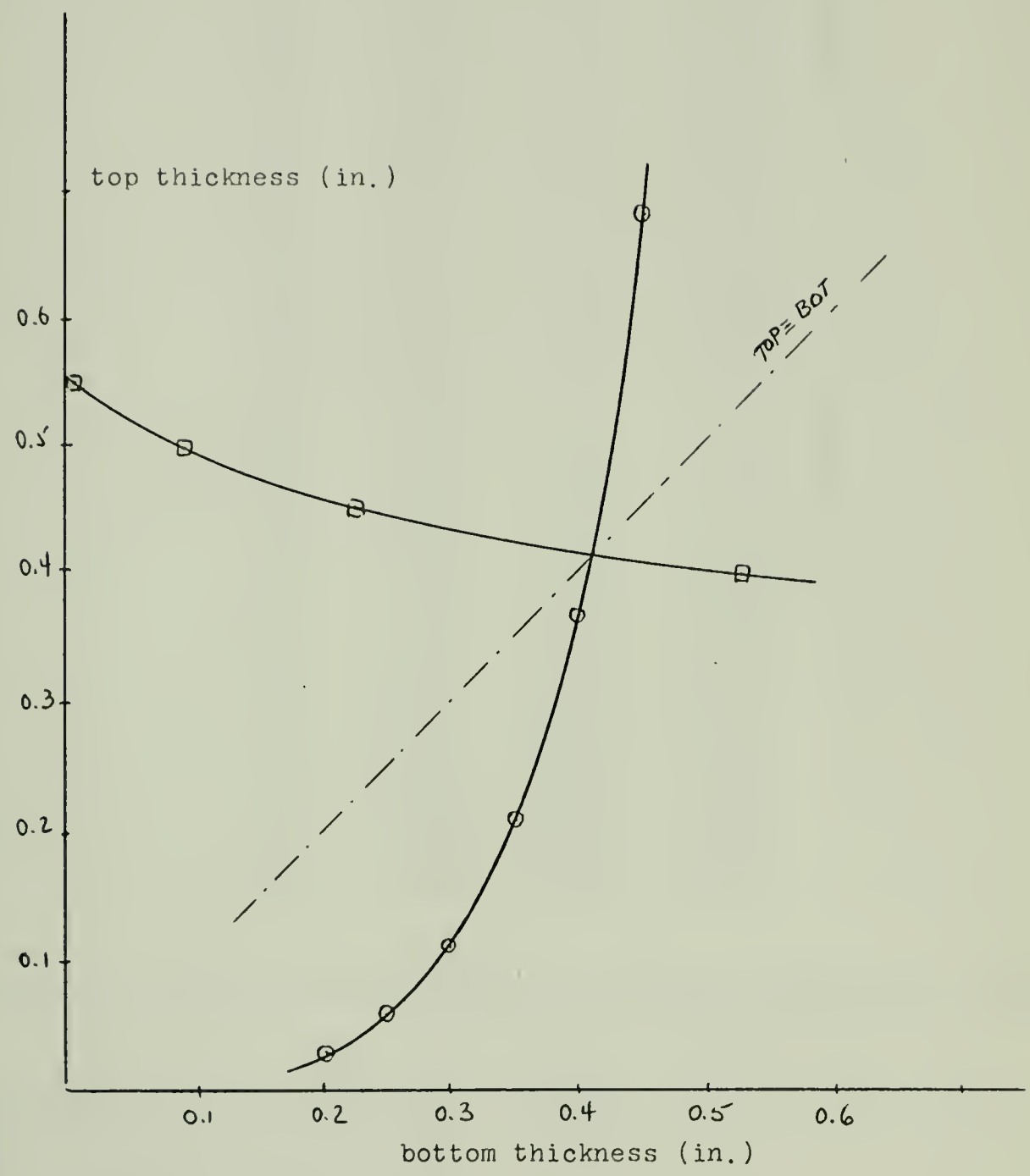
OMMON-BLOCKS:
ONE

NDEFINED SUBROUTINES:
ONE

RANSFER ADDRESS 2C72
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0033	BOT1=	0.1000
TOP1=	0.0115	BOT1=	0.1500
TOP1=	0.0288	BOT1=	0.2000
TOP1=	0.0626	BOT1=	0.2500
TOP1=	0.1156	BOT1=	0.3000
TOP1=	0.2096	BOT1=	0.3500
TOP1=	0.3737	BOT1=	0.4000
TOP1=	0.6827	BOT1=	0.4500
TOP1=	1.3697	BOT1=	0.5000
TOP1=	3.7376	BOT1=	0.5500
TOP1=	-33.1585	BOT1=	0.6000
TOP1=	-4.4245	BOT1=	0.6500
TOP1=	-2.8099	BOT1=	0.7000
TOP1=	-2.0619	BOT1=	0.7500
TOP1=	-2.0047	BOT1=	0.8000
TOP1=	-1.8681	BOT1=	0.8500
TOP1=	-1.7933	BOT1=	0.9000
TOP1=	-1.7543	BOT1=	0.9500
TOP1=	-1.7379	BOT1=	1.0000
TOP2=	0.1000	BOT2=	-0.1738
TOP2=	0.1500	BOT2=	-0.1758
TOP2=	0.2000	BOT2=	-0.2808
TOP2=	0.2500	BOT2=	-0.4765
TOP2=	0.3000	BOT2=	-1.1361
TOP2=	0.3500	BOT2=	2.8493
TOP2=	0.4000	BOT2=	0.5282
TOP2=	0.4500	BOT2=	0.2263
TOP2=	0.5000	BOT2=	0.1925
TOP2=	0.5500	BOT2=	0.2287
TOP2=	0.6000	BOT2=	0.2534
TOP2=	0.6500	BOT2=	-0.1244
TOP2=	0.7000	BOT2=	-0.1487
TOP2=	0.7500	BOT2=	-0.1888
TOP2=	0.8000	BOT2=	-0.2260
TOP2=	0.8500	BOT2=	-0.2612
TOP2=	0.9000	BOT2=	-0.2950
TOP2=	0.9500	BOT2=	-0.3276
TOP2=	1.0000	BOT2=	-0.3593


top thickness (in.)
0.6
0.5
0.4
0.3
0.2
0.1
TOP = BOT
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

BOTTOM ASSUMED LARGER THAN TOP

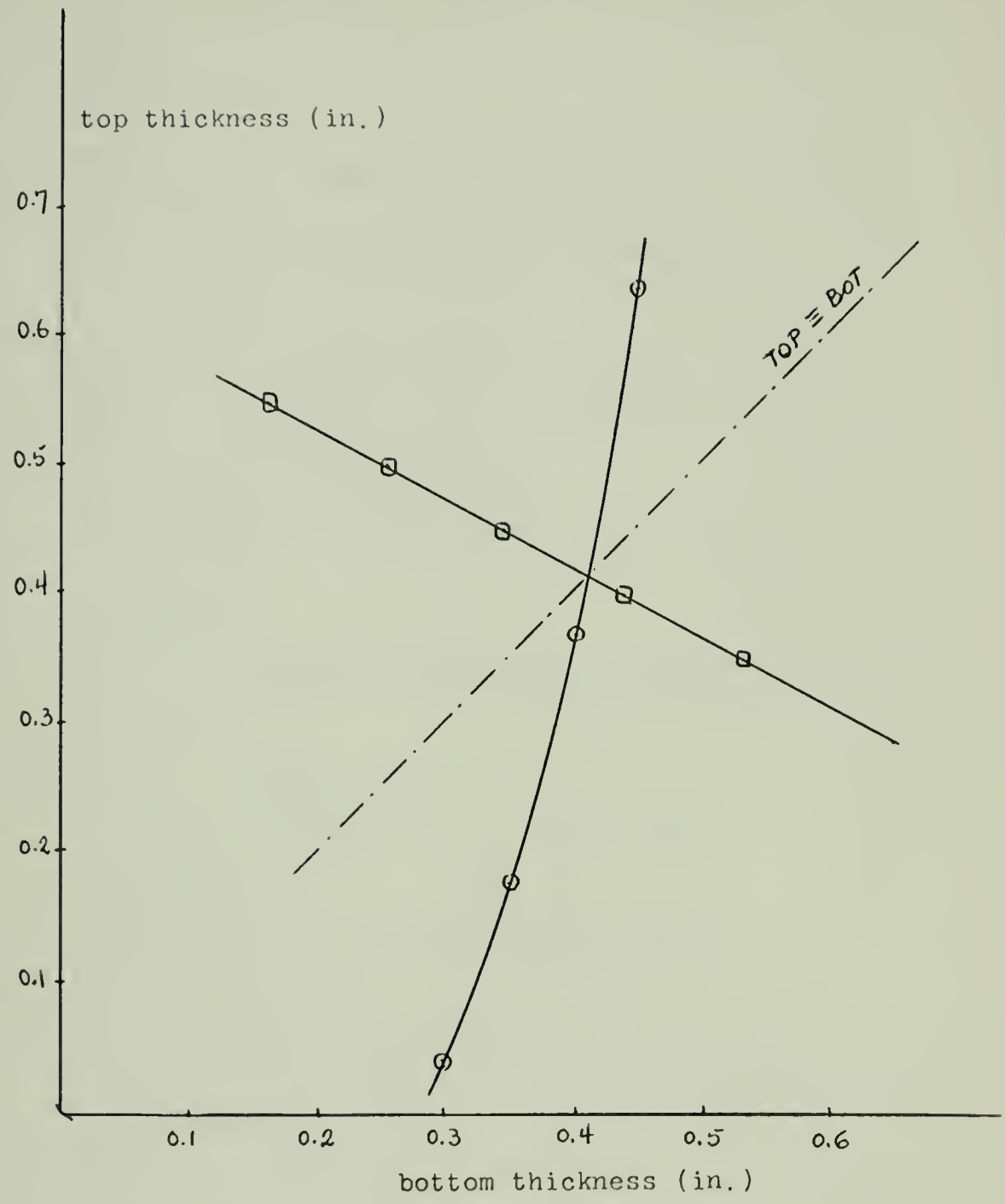
TOP3= -0.2775	BOT3= 0.1000
TOP3= -0.0949	BOT3= 0.1500
TOP3= -0.0867	BOT3= 0.2000
TOP3= -0.0444	BOT3= 0.2500
TOP3= 0.0406	BOT3= 0.3000
TOP3= 0.1769	BOT3= 0.3500
TOP3= 0.3729	BOT3= 0.4000
TOP3= 0.6371	BOT3= 0.4500
TOP3= 0.9782	BOT3= 0.5000
TOP3= 1.4047	BOT3= 0.5500
TOP3= 1.9250	BOT3= 0.6000
TOP3= 2.5478	BOT3= 0.6500
TOP3= 3.2816	BOT3= 0.7000
TOP3= 4.1349	BOT3= 0.7500
TOP3= 5.1162	BOT3= 0.8000
TOP3= 6.2340	BOT3= 0.8500
TOP3= 7.4970	BOT3= 0.9000
TOP3= 8.9137	BOT3= 0.9500
TOP3= 10.4925	BOT3= 1.0000
TOP4= 0.1000	BOT4= 0.9961
TOP4= 0.1500	BOT4= 0.9931
TOP4= 0.2000	BOT4= 0.9101
TOP4= 0.2500	BOT4= 0.7170
TOP4= 0.3000	BOT4= 0.6240
TOP4= 0.3500	BOT4= 0.5310
TOP4= 0.4000	BOT4= 0.4379
TOP4= 0.4500	BOT4= 0.3449
TOP4= 0.5000	BOT4= 0.2519
TOP4= 0.5500	BOT4= 0.1589
TOP4= 0.6000	BOT4= 0.0658
TOP4= 0.6500	BOT4= -0.0272
TOP4= 0.7000	BOT4= -0.1202
TOP4= 0.7500	BOT4= -0.2133
TOP4= 0.8000	BOT4= -0.3063
TOP4= 0.8500	BOT4= -0.3993
TOP4= 0.9000	BOT4= -0.4923
TOP4= 0.9500	BOT4= -0.5854
TOP4= 1.0000	BOT4= -0.6784

END

F VIC OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74 0

JOB HANDLING CHARGE	$ .35 / JOB	.35
173 LINES PRINTED PR2	$ 1.25 / K LN	.22
67 CARDS READ	$ 1.50 / K CD	.10
00 PLOTTER VECTORS	$ .25 / 1000	.00
20 MODEL 70 SECONDS	$25.00 / HOUR	.14
00 MODEL 80 SECONDS	$12.50 / HOUR	.00
	TOTAL CHARGE $	.81

REIN 490 14731 LOGGED OUT 05/06/74 15:20. $ 13.29 LEFT AFTER 18 LOGINS.


top thickness (in.)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
TOP ≡ BOT
0.1
0.2
0.3
0.4
0.5
0.6
bottom thickness (in.)

```
0004     C      *AL* IS THE LENGHT
0004            AL=500.
000C            B=AL/8.
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.
0024            D=AL/9.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR STEEL
0030            POI=0.3
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR STEEL
0038            E=30.*10.**6
0040     C      *DST* IS THE DESIGN STRESS
0040            DST=20000.
0054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0054            S=30.
0050     C      *BM* IS THE BENDING MOMENT
0050            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
0058            G=0.33396*S*S*(1.-POI*POI)/E
0064     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
0064     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0064            TOP=0.4125
0070            BOT=0.4125
0074            A=560.*BM*(B*BOT+D*TOP)
0080            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
0140     C      *STH* IS THE STRESS ON TOP DUE TO HOGGING
0140            STH=A/DEN
0150            WRITE(5,60)STH
0174       60 FORMAT(' ',20X,'STH='F10.3)
0180            C=560.*BM*(B*TOP+D*TOP)
0184     C      *SBH* IS THE STRESS ON BOT DUE TO HOGGING
0184            SBH=C/DEN
0104            WRITE(5,90)SBH
0200       90 FORMAT(' ',20X,'SBH='F10.3)
0210     C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
0210            SBCRIT=BOT*BOT/3
0220            WRITE(5,110)SBCRIT
0228      110 FORMAT(' ',17X,'SBCRIT='F10.3)
0244            P=2.*D*TOP+B*(TOP+BOT)
0248     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
0248            DITOP=D*(B*BOT+D*TOP)/P
0260            WRITE(5,40)DITOP
0268       40 FORMAT(' ',18X,'DITOP='F10.4)
0204     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0204            DIBOT=D*(B*TOP+D*TOP)/P
0288            WRITE(5,50)DIBOT
0304       50 FORMAT(' ',18X,'DIBOT='F10.4)
0320            END

0.[S] .U        0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
44[V] POI       034C[V] E       0007[S] .R      035C[V] DST     0364[V] S
68[V] BM        037C[V] G       0388[V] TOP     0390[V] BOT     0394[V] A
84[V] DEN       03B4[V] STH     0174[L] 62      0000[S] @I      03B8[V] C
```

```
C(V) SBH      01E2(L) 90      03C2(V) SBCRIT  0228(L) 110     03C4(V) P
>(V) DITOP    02A8(L) 40      03CC(V) DIBOT   0304(L) 50      0000(S) .V
>EQ         L
F


OGRAM LABELS:
2070 .MAIN.    2A60 .V        2890 .COMP     2A6E @I        2440 .R        2958 .ZE
2880 $6        2480 .A        2984 .MES      2832 .W        263A EXP       27C0 AIN
2532 ALOG      28F8 .RARG     2954 .5        263A AEXP      295C .ERCNT    292A $8
295C .O        2A32 .U        3882A
```



```
NO ERBLOCKS:
.E


EFINED SUBROUTINES:
.E


ANSFER ADDRESS 2070
CUTION BEGINS:

               STH= 2.037.113
               SBH= 2.037.113
            SBCRIT= 2.505.348
             DITOP=    27.7778
             DIBOT=    27.7778
END


F VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0


JOB HANDLING CHARGE    $   .35 / JOB          .35
 85 LINES PRINTED PR2  $ 1.25 / K LN          .11
 54 CARDS READ         $ 1.50 / K CD          .08
 00 PLOTTER VECTORS    $   .25 / 1000         .00
 13 MODEL 70 SECONDS   $25.00 / HOUR          .09
 00 MODEL 80 SECONDS   $12.50 / HOUR          .00
                        TOTAL CHARGE $        .63


EIR 490 14731  LOGGED OUT 05/06/74 15:46.  $  11.16 LEFT AFTER    21 LOGINS.
```

SUMMARY

Length	= 500 ft
Beam	= AL/8
Draft	= B/3
Depth	= AL/9
DST	= 20000 psi
S	= 30"
Material	- STEEL
TOP	= 0.4125"
BOT	= 0.4125"
STH	= 20037.11
SBH	= 20037.11
SBCRIT	= 20505.43
DITOP	= 27.78'
DIBOT	= 27.78'

Note that this is the case where two acceptable solutions exist although they end up being the same because TOP=BOT.

Note that the neutral axis is located half way between top and bottom and the stress is the same at the top and at the bottom, as it was expected beforehand.

```
1004     C      *AL* IS THE LENGHT
1014           AL=500.
102C           B=AL/8.
1218     C      *DRA* IS THE DRAFT
1218           DRA=B/3.
1024           D=AL/9.
1030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
1030     C      FOR STEEL
1030           POI=0.3
1038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
1038     C      FOR STEEL
1040           E=30.*10.**6
1048     C      *DST* IS THE DESIGN STRESS
104C           DST=20000.
1054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
1054           S=120.
105C     C      *BM* IS THE BENDING MOMENT
1060           BM=(B*DRA*AL*AL*0.75)/(35.*35.)
1068           G=0.39396*S*S*(1.-POI*POI)/E
1074           A=9.*B*B*D/(14.*BM)
1080           C=3.*B*D*D/(7.*BM)
108C           F=3.*D*D*D/(14.*BM)
1098     C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
1098           WRITE(5,10)
10A4       10  FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
10B0     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
10B0     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
10B0           BOT1=1.
10BC       11  TOP1=B*B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
10D8           WRITE(5,20)TOP1,BOT1
10E8       20  FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
10F4           BOT1=BOT1+0.25
1100           IF(BOT1.GT.2.)GO TO 30
1108           GO TO 11
1110       30  TOP2=0.02
1114       31  BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
1120           WRITE(5,40)TOP2,BOT2
1128       40  FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
1134           TOP2=TOP2+0.02
113C           IF(TOP2.GT.1.)GO TO 50
1144           GO TO 31
1148       50  CONTINUE
1148     C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
1148           WRITE(5,60)
1150       60  FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
1160           BOT3=1.
1168       61  TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
1174           WRITE(5,70)TOP3,BOT3
1188       70  FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
1190           BOT3=BOT3+0.25
119C           IF(BOT3.GT.2.)GO TO 80
11A8           GO TO 61
```

```
'402        80 TOP4=0.02
'40A        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
'44E           WRITE(5,90)TOP4,BOT4
'472        90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
'49A           TOP4=TOP4+0.02
'4A6           IF(TOP4.GT.1.)GO TO 100
'4B8           GO TO 81
'4BC       100 CONTINUE
'4BC           END
'0[S] .U       04C0[V] AL      04C8[V] B       04D0[V] DRA     04D8[V] D
'E0[V] POI     04E8[V] E       0000[S] .R      04F8[V] DST     0500[V] S
'08[V] BM      051C[V] G       0528[V] A       0530[V] C       0538[V] F
'00[L] 10      0000[S] @I      053C[V] BOT1    0176[L] 11      0540[V] TOP1
'22[L] 20      022C[L] 30      0554[V] TOP2    0234[L] 31      055C[V] BOT2
'34[L] 40      02FE[L] 50      0312[L] 60      056C[V] BOT3    0348[L] 61
'70[V] TOP3    038E[L] 70      0402[L] 80      0574[V] TOP4    040A[L] 81
'78[V] BOT4    0472[L] 90      04BC[L] 100     0000[S] .V
 XEQ          L
OF


ROGRAM LABELS:
 2070 *MAIN*   2C0C .V        2A3C .COMP      2C1A @I         25EC .R         2B04 .ZE
 2A62 $6       262C .A         2B60 .MES       29DE .W         27E6 EXP        296C AI
 26DE ALOG     2AA4 .RARG      2800 .5         27E6 AEXP       2B08 .ERCNT     2AD6 $8
 2B0A .0       2BDE .U         3D36

NTRY-POINTS:
 25EC .R       262C .A         26DE ALOG       27E6 AEXP       27E6 EXP        296C AI
 29DE .W       2A3C .COMP      2A62 $6         2AA4 .RARG      2AD6 $8         2B00 .5
 2B04 .ZERO    2B08 .ERCNT     2B0A .0         2B60 .MES       2BEA .U         2C10 .V
 2C1A @I

OMMON-BLOCKS:
ONE

NDEFINED SUBROUTINES:
ONE

RANSFER ADDRESS 2070
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.2423	BOT1=	1.0000
TOP1=	0.2868	BOT1=	1.0500
TOP1=	0.3378	BOT1=	1.1000
TOP1=	0.3960	BOT1=	1.1500
TOP1=	0.4626	BOT1=	1.2000
TOP1=	0.5385	BOT1=	1.2500
TOP1=	0.6253	BOT1=	1.3000
TOP1=	0.7245	BOT1=	1.3500
TOP1=	0.8382	BOT1=	1.4000
TOP1=	0.9688	BOT1=	1.4500
TOP1=	1.1191	BOT1=	1.5000
TOP1=	1.2929	BOT1=	1.5500
TOP1=	1.4947	BOT1=	1.6000
TOP1=	1.7305	BOT1=	1.6500
TOP1=	2.0078	BOT1=	1.7000
TOP1=	2.3366	BOT1=	1.7500
TOP1=	2.7305	BOT1=	1.8000
TOP1=	3.2081	BOT1=	1.8500
TOP1=	3.7959	BOT1=	1.9000
TOP1=	4.5327	BOT1=	1.9500
TOP1=	5.4783	BOT1=	2.0000
TOP2=	0.0200	BOT2=	-0.0182
TOP2=	0.0400	BOT2=	-0.0375
TOP2=	0.0600	BOT2=	-0.0579
TOP2=	0.0800	BOT2=	-0.0799
TOP2=	0.1000	BOT2=	-0.1038
TOP2=	0.1200	BOT2=	-0.1301
TOP2=	0.1400	BOT2=	-0.1595
TOP2=	0.1600	BOT2=	-0.1932
TOP2=	0.1800	BOT2=	-0.2328
TOP2=	0.2000	BOT2=	-0.2808
TOP2=	0.2200	BOT2=	-0.3417
TOP2=	0.2400	BOT2=	-0.4234
TOP2=	0.2600	BOT2=	-0.5421
TOP2=	0.2800	BOT2=	-0.7376
TOP2=	0.3000	BOT2=	-1.1361
TOP2=	0.3200	BOT2=	-2.4815
TOP2=	0.3400	BOT2=	10.9162
TOP2=	0.3600	BOT2=	1.6081
TOP2=	0.3800	BOT2=	0.8255
TOP2=	0.4000	BOT2=	0.5282
TOP2=	0.4200	BOT2=	0.3680
TOP2=	0.4400	BOT2=	0.2655
TOP2=	0.4600	BOT2=	0.1926
TOP2=	0.4800	BOT2=	0.1371
TOP2=	0.5000	BOT2=	0.0925
TOP2=	0.5200	BOT2=	0.0553
TOP2=	0.5400	BOT2=	0.0233
TOP2=	0.5600	BOT2=	-0.0050
TOP2=	0.5800	BOT2=	-0.0303
TOP2=	0.6000	BOT2=	-0.0534
TOP2=	0.6200	BOT2=	-0.0748
TOP2=	0.6400	BOT2=	-0.0948
TOP2=	0.6600	BOT2=	-0.1136
TOP2=	0.6800	BOT2=	-0.1315

TOP2=	0.7000	BOT2=	-0.1487
TOP2=	0.7200	BOT2=	-0.1651
TOP2=	0.7400	BOT2=	-0.1810
TOP2=	0.7600	BOT2=	-0.1964
TOP2=	0.7800	BOT2=	-0.2114
TOP2=	0.8000	BOT2=	-0.2260
TOP2=	0.8200	BOT2=	-0.2403
TOP2=	0.8400	BOT2=	-0.2543
TOP2=	0.8600	BOT2=	-0.2681
TOP2=	0.8800	BOT2=	-0.2816
TOP2=	0.9000	BOT2=	-0.2950
TOP2=	0.9200	BOT2=	-0.3081
TOP2=	0.9400	BOT2=	-0.3211
TOP2=	0.9600	BOT2=	-0.3340
TOP2=	0.9800	BOT2=	-0.3467
TOP2=	1.0000	BOT2=	-0.3593

Note that in this case by simple inspection of the coordinates of the points to be ploted we can see that the intersection will occur outside the acceptable range.

Note also that in order to obtain the coordinates of the points within a range of interest where the intersection may occur, different ranges and increments are considered in each program. This could be improved if at that time these printouts were available and a better idea of the thicknesses that should be expected existed.

BOTTOM ASSUMED LARGER THAN TOP

TOP3= -0.1776	BOT3= 1.0000
TOP3= -0.1099	BOT3= 1.0500
TOP3= -0.0310	BOT3= 1.1000
TOP3= 0.0596	BOT3= 1.1500
TOP3= 0.1625	BOT3= 1.2000
TOP3= 0.2782	BOT3= 1.2500
TOP3= 0.4072	BOT3= 1.3000
TOP3= 0.5501	BOT3= 1.3500
TOP3= 0.7074	BOT3= 1.4000
TOP3= 0.8797	BOT3= 1.4500
TOP3= 1.0674	BOT3= 1.5000
TOP3= 1.2711	BOT3= 1.5500
TOP3= 1.4914	BOT3= 1.6000
TOP3= 1.7287	BOT3= 1.6500
TOP3= 1.9836	BOT3= 1.7000
TOP3= 2.2567	BOT3= 1.7500
TOP3= 2.5484	BOT3= 1.8000
TOP3= 2.8594	BOT3= 1.8500
TOP3= 3.1901	BOT3= 1.9000
TOP3= 3.5410	BOT3= 1.9500
TOP3= 3.9128	BOT3= 2.0000
TOP4= 0.0200	BOT4= 1.1450
TOP4= 0.0400	BOT4= 1.1078
TOP4= 0.0600	BOT4= 1.0775
TOP4= 0.0800	BOT4= 1.0533
TOP4= 0.1000	BOT4= 0.9961
TOP4= 0.1200	BOT4= 0.9589
TOP4= 0.1400	BOT4= 0.9217
TOP4= 0.1600	BOT4= 0.8845
TOP4= 0.1800	BOT4= 0.8473
TOP4= 0.2000	BOT4= 0.8101
TOP4= 0.2200	BOT4= 0.7728
TOP4= 0.2400	BOT4= 0.7356
TOP4= 0.2600	BOT4= 0.6984
TOP4= 0.2800	BOT4= 0.6612
TOP4= 0.3000	BOT4= 0.6240
TOP4= 0.3200	BOT4= 0.5868
TOP4= 0.3400	BOT4= 0.5496
TOP4= 0.3600	BOT4= 0.5124
TOP4= 0.3800	BOT4= 0.4752
TOP4= 0.4000	BOT4= 0.4379
TOP4= 0.4200	BOT4= 0.4007
TOP4= 0.4400	BOT4= 0.3635
TOP4= 0.4600	BOT4= 0.3263
TOP4= 0.4800	BOT4= 0.2891
TOP4= 0.5000	BOT4= 0.2519
TOP4= 0.5200	BOT4= 0.2147
TOP4= 0.5400	BOT4= 0.1775
TOP4= 0.5600	BOT4= 0.1403
TOP4= 0.5800	BOT4= 0.1030
TOP4= 0.6000	BOT4= 0.0658
TOP4= 0.6200	BOT4= 0.0286
TOP4= 0.6400	BOT4= -0.0086
TOP4= 0.6600	BOT4= -0.0458
TOP4= 0.6800	BOT4= -0.0830

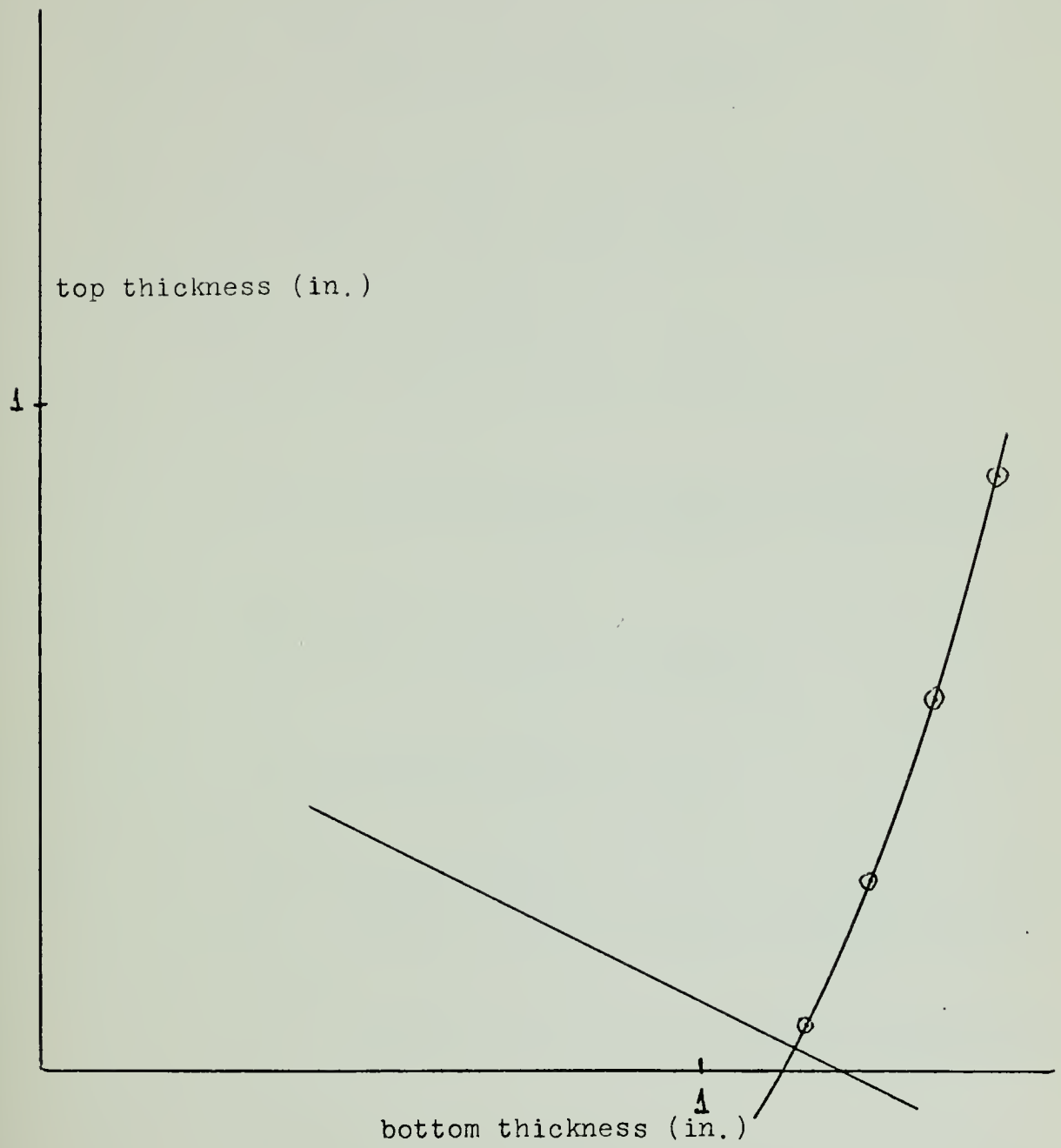
```
TOP4=    0.7777      BOT4=   -2.1202
TOP4=    0.7777      BOT4=   -2.1574
TOP4=    0.7777      BOT4=   -2.1946
TOP4=    0.7800      BOT4=   -2.2319
TOP4=    0.7800      BOT4=   -2.2691
TOP4=    0.7800      BOT4=   -2.3063
TOP4=    0.7800      BOT4=   -2.3435
TOP4=    0.7800      BOT4=   -2.3807
TOP4=    0.7800      BOT4=   -2.4179
TOP4=    0.7800      BOT4=   -2.4551
TOP4=    0.7800      BOT4=   -2.4923
TOP4=    0.7800      BOT4=   -2.5296
TOP4=    0.7800      BOT4=   -2.5668
TOP4=    0.7800      BOT4=   -2.6040
TOP4=    0.7800      BOT4=   -2.6412
TOP4=    1.0000      BOT4=   -2.6784

END

OF VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0


 JOB HANDLING CHARGE    $   .35 / JOB          .35
239 LINES PRINTED PR2   $ 1.25 / K LN          .30
  67 CARDS READ         $ 1.50 / K CD          .10
  00 PLOTTER VECTORS    $   .25 / 1000         .00
  17 MODEL 70 SECONDS   $25.00 / HOUR          .12
  00 MODEL 80 SECONDS   $12.50 / HOUR          .00
                         TOTAL CHARGE $        .87


RFEIR 490 14731  LOGGED OUT 05/06/74 15:25.  $  12.42 LEFT AFTER    19 LOGINS.
```


top thickness (in.)
1
1
bottom thickness (in.)

```
C       *AL* IS THE LENGTH
        AL=5
        G=AL/5.
C       *DA* IS THE DRAFT
        D=A/3.
        D=AL/5.
C       *S(1)* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        S(1)= .3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=3.*10.**6
C       *FST* IS THE MEAN STRESS
        FST=2
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=12.
C       *B(1)* IS THE
        B=( *AL*AL  .7E)/(36.*35.)
        F=.7 3*S*S*(1.+S(1))*B(1)/E
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *T(1)* IS THE THICKNESS OF THE BOTTOM PLATING
        TOP= .
        BOT=1.1
        A=5 .**2*(5*B(1)+B(1)*B(1)
        DA=' *( .**3+T  *.0)+2.*B*B*3.0*(TOP+BOT)+(B*B*TOP*BOT))
C       *STH* IS THE STRESS ON TOP DUE TO BOGGING
        ST=A/3.
        WRITE(3,4)STH
4       F( *,T(' ',2 X,'ST=',F1 .3)
        T=5 .**2*(B+TOP+BOT)*B(1)
C       *SB* IS THE STRESS ON BOT DUE TO BOGGING
        SB=C/3
        WRITE(3,55)SB
55      F(5X,'SB=',F1 .3)
C       *SIGTOP* IS THE CRITICAL STRESS ON BOT
        SIGTOP= BOT*BOT/
        WRITE(3,11 )SIGTOP
11      FORMAT(' ',17X,'SIGTOP=',F1 .3)
        D=2.*B*B(1)+B*(T .+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=  (  **2+ **2 T)/
        WRITE(3,4 )DITOP
4       F(5X,'DITOP=',F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=3*(  +DITOP+ *BOT)/
        WRITE(3,5 )DIBOT
5       FORMAT(5X,'DIBOT=',F10.4)
        STOP
        END
```

```
[S] ..      0244[V] AL      33C[V] B       0304[V] DBA     033C[V] D
[V] DOI     034C[V] E       ***[S] .B       33C[V] DST     0364[V] S
[V] ...     03C[V] T        33C[V] TOP     0304[V] BOT     039C[V] A
[V] SIG     02C[V] STH      0744[V] 66     0***[S] 6I      03C*[V] C
```

SUMMARY

Length	= 500'
Beam	= AL/8
Draft	= B/3
Depth	= AL/9
DST	= 20000 psi
S	= 120"
Material	- STEEL
TOP	= 0.03"
BOT	= 1.14"
STH	= 19771.88
SBH	= 9579.87
SBCRIT	= 9788.37
DITOP	= 37.42'
DIBOT	= 18.13'

Note in this case the large value chosen for S and associated with it the large value required for the thickness at the bottom to avoid buckling which nevertheless does not resist stresses larger than 9788 psi in compression.

If we look now at these three cases, all for the same material and set of dimensions (same bending moment) we can see how the thicknesses and neutral axis position changed as the value of S was changed.

CASE	S inches	TOP inches	BOT inches	SBH psi	SBCRIT psi	DITOP ft	DIBOT ft
1	10	0.468	0.166	30000	30000	22.06	33.05
2	30	0.4125	0.4125	20000	20000	27.78	27.78
3	120	0.03	1.14	9700	9700	37.43	18.13

In this table, we can more readily make conclusions on the influence of the value chosen for S on the neutral axis location, and also a quick look at the resulting values for the thicknesses may give an idea of the weight associated with each case.

In the following cases the dimension parameters are changed (increased) and consequently the bending moment and the thicknesses of plating will be higher.

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            G=0.3936*S*S*(1.-POI*POI)/E
            A=9.*B*B*D/(14.*BM)
            C=3.*B*D*D/(70.*BM)
            F=3.*D*D*D/(14.*BM)
      C     THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
            WRITE(5,10)
         10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT1=0.1
         11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
            WRITE(5,20)TOP1,BOT1
         20 FORMAT(' ',25X,'TOP1='F9.4,5X,'BOT1='F9.4)
            BOT1=BOT1+0.25
            IF(BOT1.GT.2.)GO TO 30
            GO TO 11
         30 TOP2=1.
         31 BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
            WRITE(5,40)TOP2,BOT2
         40 FORMAT(' ',25X,'TOP2='F9.4,5X,'BOT2='F9.4)
            TOP2=TOP2+0.5
            IF(TOP2.GT.15.)GO TO 50
            GO TO 31
         50 CONTINUE
      C     THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
            WRITE(5,60)
         60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
            BOT3=0.1
         61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
            WRITE(5,70)TOP3,BOT3
         70 FORMAT(' ',25X,'TOP3='F9.4,5X,'BOT3='F9.4)
            BOT3=BOT3+0.25
            IF(BOT3.GT.3.)GO TO 80
            GO TO 61
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
.02        80 TOP4=1.
.0A        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
.4E           WRITE(5,90)TOP4,BOT4
.72        90 FORMAT(' ',25X,'TOP4='F9.4,5X,'BOT4='F9.4)
.9A           TOP4=TOP4+.5
.A6           IF(TOP4.GT.15.)GO TO 100
.B8           GO TO 81
.5C       100 CONTINUE
.BC           END
```

```
(S) .U      04C0[V] AL      04C8[V] B       04D0[V] DRA     04D8[V] D
(V) POI     04F8[V] E       0000[S] .R      04F8[V] DST     0500[V] S
(V) BM      0518[V] G       0524[V] A       0530[V] C       053C[V] F
(L) 10      0000[S] @I      0540[V] BOT1    0176[L] 11      0548[V] TOP1
(L) 20      022C[L] 30      055C[V] TOP2    0234[L] 31      0560[V] BOT2
(L) 40      02FE[L] 50      0312[L] 60      0578[V] BOT3    0348[L] 61
(V) TOP3    0388[L] 70      0402[L] 80      0580[V] TOP4    040A[L] 81
(V) BOT4    0472[L] 90      048C[L] 100     0200[S] .V
E0          L
```

```
GRAM LABELS:
207 .MAIN.    2C18 .V       2A48 .COMP    2C26 @I       25F8 .R       2B10 .ZE
A6E $6        2638 .A       2B6C .MES     29EA .W       27F2 EXP      2978 AIN
6EA ALOG      2AB0 .RARG    2B0C .5       27F2 AEXP     2B14 .ERCNT   2AE2 $8
B14 .O        2BEA .U       3D42
```

```
RY-POINTS:
5F8 .R        2638 .A       26EA ALOG     27F2 AEXP     27F2 EXP      2978 AIN
9EA .W        2A48 .COMP    2A6E $6       2AB0 .RARG    2AE2 $8       2B0C .5
B10 .ZERO     2B14 .ERCNT   2B16 .O       2B6C .MES     2BF6 .U       2C1C .V
C26 @I
```

```
MON-BLOCKS:
E
```

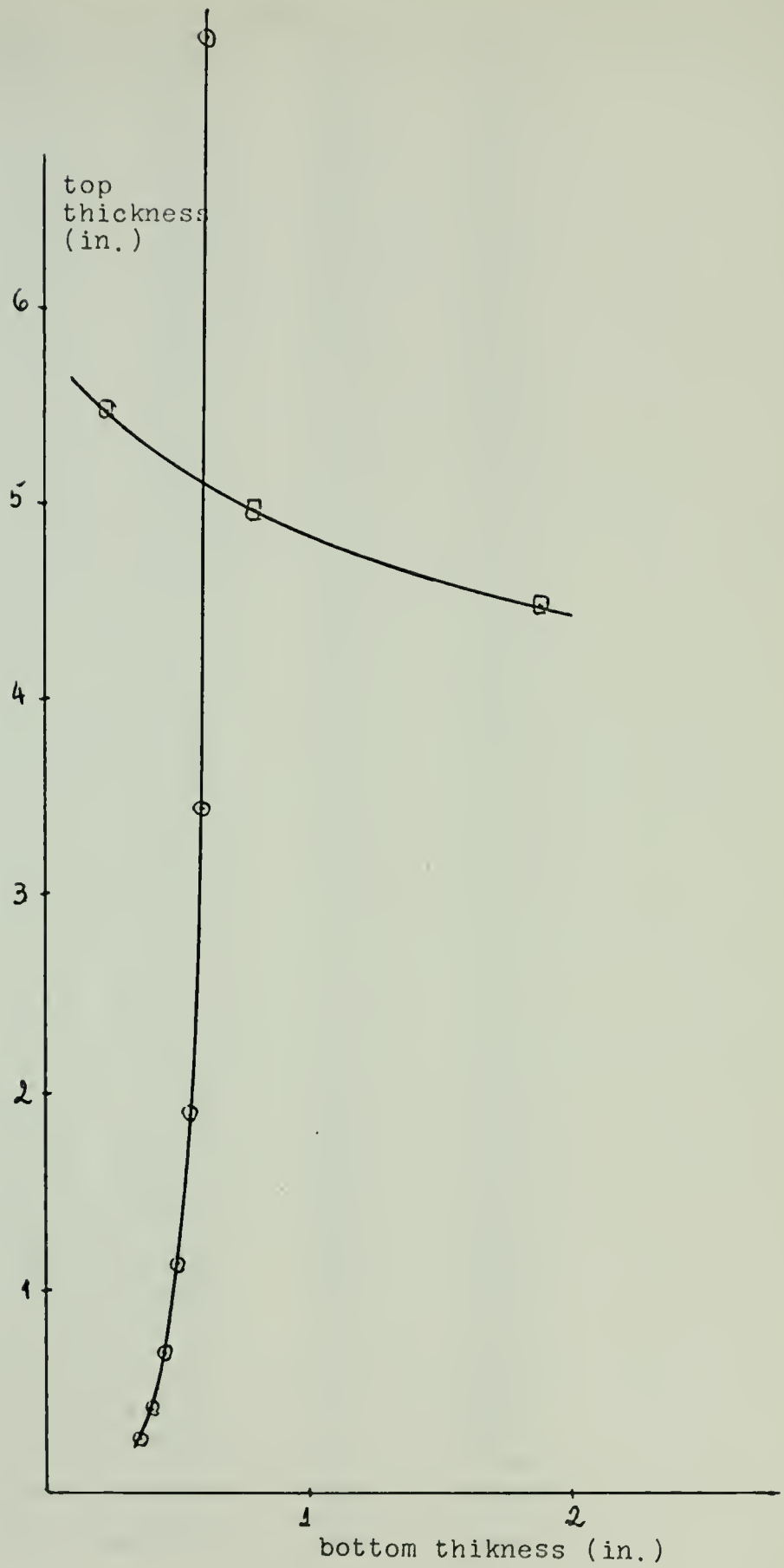
```
EFINED SUBROUTINES:
E
```

```
NSFER ADDRESS 2070
UTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0048	BOT1=	0.1000
TOP1=	0.0168	BOT1=	0.1500
TOP1=	0.0412	BOT1=	0.2000
TOP1=	0.0844	BOT1=	0.2500
TOP1=	0.1554	BOT1=	0.3000
TOP1=	0.2673	BOT1=	0.3500
TOP1=	0.4414	BOT1=	0.4000
TOP1=	0.7145	BOT1=	0.4500
TOP1=	1.1570	BOT1=	0.5000
TOP1=	1.9240	BOT1=	0.5500
TOP1=	3.4364	BOT1=	0.6000
TOP1=	7.3849	BOT1=	0.6500
TOP1=	36.2430	BOT1=	0.7000
TOP1=	-20.7688	BOT1=	0.7500
TOP1=	-9.8191	BOT1=	0.8000
TOP1=	-7.1387	BOT1=	0.8500
TOP1=	-5.9771	BOT1=	0.9000
TOP1=	-5.3601	BOT1=	0.9500
TOP1=	-5.0000	BOT1=	1.0000
TOP1=	-4.7816	BOT1=	1.0500
TOP1=	-4.6498	BOT1=	1.1000
TOP1=	-4.5747	BOT1=	1.1500
TOP1=	-4.5388	BOT1=	1.2000
TOP1=	-4.5313	BOT1=	1.2500
TOP1=	-4.5450	BOT1=	1.3000
TOP1=	-4.5748	BOT1=	1.3500
TOP1=	-4.6173	BOT1=	1.4000
TOP1=	-4.6700	BOT1=	1.4500
TOP1=	-4.7309	BOT1=	1.5000
TOP1=	-4.7986	BOT1=	1.5500
TOP1=	-4.8720	BOT1=	1.6000
TOP1=	-4.9502	BOT1=	1.6500
TOP1=	-5.0325	BOT1=	1.7000
TOP1=	-5.1183	BOT1=	1.7500
TOP1=	-5.2071	BOT1=	1.8000
TOP1=	-5.2986	BOT1=	1.8500
TOP1=	-5.3924	BOT1=	1.9000
TOP1=	-5.4883	BOT1=	1.9500
TOP1=	-5.5860	BOT1=	2.0000
TOP2=	1.0000	BOT2=	-0.4473
TOP2=	1.5000	BOT2=	-0.7727
TOP2=	2.0000	BOT2=	-1.1829
TOP2=	2.5000	BOT2=	-1.8315
TOP2=	3.0000	BOT2=	-3.2461
TOP2=	3.5000	BOT2=	-11.8971
TOP2=	4.0000	BOT2=	5.8810
TOP2=	4.5000	BOT2=	1.8850
TOP2=	5.0000	BOT2=	0.8127
TOP2=	5.5000	BOT2=	0.2578
TOP2=	6.0000	BOT2=	-0.1140
TOP2=	6.5000	BOT2=	-0.4000
TOP2=	7.0000	BOT2=	-0.6389
TOP2=	7.5000	BOT2=	-0.8492
TOP2=	8.0000	BOT2=	-1.0408
TOP2=	8.5000	BOT2=	-1.2195

TOP2=	9.0000	BOT2=	-1.3890
TOP2=	9.5000	BOT2=	-1.5516
TOP2=	10.0000	BOT2=	-1.7090
TOP2=	10.5000	BOT2=	-1.8623
TOP2=	11.0000	BOT2=	-2.0124
TOP2=	11.5000	BOT2=	-2.1599
TOP2=	12.0000	BOT2=	-2.3052
TOP2=	12.5000	BOT2=	-2.4487
TOP2=	13.0000	BOT2=	-2.5907
TOP2=	13.5000	BOT2=	-2.7314
TOP2=	14.0000	BOT2=	-2.8711
TOP2=	14.5000	BOT2=	-3.0098
TOP2=	15.0000	BOT2=	-3.1477


top
thickness
(in.)
6
5
4
3
2
1
1
2
bottom thikness (in.)

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	-0.0316	BOT3=	0.1000
TOP3=	-0.0297	BOT3=	0.1500
TOP3=	-0.0066	BOT3=	0.2000
TOP3=	0.0449	BOT3=	0.2500
TOP3=	0.1318	BOT3=	0.3000
TOP3=	0.2612	BOT3=	0.3500
TOP3=	0.4402	BOT3=	0.4000
TOP3=	0.6758	BOT3=	0.4500
TOP3=	0.9752	BOT3=	0.5000
TOP3=	1.3455	BOT3=	0.5500
TOP3=	1.7926	BOT3=	0.6000
TOP3=	2.3268	BOT3=	0.6500
TOP3=	2.9524	BOT3=	0.7000
TOP3=	3.6764	BOT3=	0.7500
TOP3=	4.5071	BOT3=	0.8000
TOP3=	5.4511	BOT3=	0.8500
TOP3=	6.5155	BOT3=	0.9000
TOP3=	7.7074	BOT3=	0.9500
TOP3=	9.0339	BOT3=	1.0000
TOP3=	10.5021	BOT3=	1.0500
TOP3=	12.1190	BOT3=	1.1000
TOP3=	13.8917	BOT3=	1.1500
TOP3=	15.8273	BOT3=	1.2000
TOP3=	17.9330	BOT3=	1.2500
TOP3=	20.2157	BOT3=	1.3000
TOP3=	22.6826	BOT3=	1.3500
TOP3=	25.3407	BOT3=	1.4000
TOP3=	28.1972	BOT3=	1.4500
TOP3=	31.2591	BOT3=	1.5000
TOP3=	34.5334	BOT3=	1.5500
TOP3=	38.0274	BOT3=	1.6000
TOP3=	41.7480	BOT3=	1.6500
TOP3=	45.7024	BOT3=	1.7000
TOP3=	49.8976	BOT3=	1.7500
TOP3=	54.3407	BOT3=	1.8000
TOP3=	59.0389	BOT3=	1.8500
TOP3=	63.9990	BOT3=	1.9000
TOP3=	69.2283	BOT3=	1.9500
TOP3=	74.7339	BOT3=	2.0000
TOP3=	80.5228	BOT3=	2.0500
TOP3=	86.6022	BOT3=	2.1000
TOP3=	92.9790	BOT3=	2.1500
TOP3=	99.6604	BOT3=	2.2000
TOP3=	106.6534	BOT3=	2.2500
TOP3=	113.9652	BOT3=	2.3000
TOP3=	121.6029	BOT3=	2.3500
TOP3=	129.5735	BOT3=	2.4000
TOP3=	137.8842	BOT3=	2.4500
TOP3=	146.5416	BOT3=	2.5000
TOP3=	155.5534	BOT3=	2.5500
TOP3=	164.9265	BOT3=	2.6000
TOP3=	174.6679	BOT3=	2.6500
TOP3=	184.7845	BOT3=	2.7000
TOP3=	195.2838	BOT3=	2.7500
TOP3=	206.1726	BOT3=	2.8000

```
TOP3= 217.4581      BOT3=   2.8500
TOP3= 229.1475      BOT3=   2.9000
TOP3= 241.2473      BOT3=   2.9500
TOP3= 253.7654      BOT3=   3.0000
TOP4=   1.0000      BOT4=  16.1639
TOP4=   1.5000      BOT4=  14.2342
TOP4=   2.0000      BOT4=  12.3044
TOP4=   2.5000      BOT4=  10.3746
TOP4=   3.0000      BOT4=   8.4448
TOP4=   3.5000      BOT4=   6.5150
TOP4=   4.0000      BOT4=   4.5852
TOP4=   4.5000      BOT4=   2.6554
TOP4=   5.0000      BOT4=   0.7256
TOP4=   5.5000      BOT4=  -1.2042
TOP4=   6.0000      BOT4=  -3.1340
TOP4=   6.5000      BOT4=  -5.0638
TOP4=   7.0000      BOT4=  -6.9936
TOP4=   7.5000      BOT4=  -8.9234
TOP4=   8.0000      BOT4= -10.8532
TOP4=   8.5000      BOT4= -12.7829
TOP4=   9.0000      BOT4= -14.7127
TOP4=   9.5000      BOT4= -16.6425
TOP4=  10.0000      BOT4= -18.5723
TOP4=  10.5000      BOT4= -20.5021
TOP4=  11.0000      BOT4= -22.4319
TOP4=  11.5000      BOT4= -24.3617
TOP4=  12.0000      BOT4= -26.2915
TOP4=  12.5000      BOT4= -28.2213
TOP4=  13.0000      BOT4= -30.1511
TOP4=  13.5000      BOT4= -32.0808
TOP4=  14.0000      BOT4= -34.0106
TOP4=  14.5000      BOT4= -35.9404
TOP4=  15.0000      BOT4= -37.8702
```

```
VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0

JOB HANDLING CHARGE    $  .35 / JOB          .35
253 LINES PRINTED PR2  $ 1.25 / K LN         .32
67 CARDS READ          $ 1.50 / K CD         .10
00 PLOTTER VECTORS     $  .25 / 1000         .00
17 MODEL 70 SECONDS    $25.00 / HOUR         .12
00 MODEL 80 SECONDS    $12.50 / HOUR         .00
                        TOTAL CHARGE $       .89

PEIR 490 14731  LOGGED OUT 05/06/74 17:26.  $   9.62 LEFT AFTER    23 LOGINS.
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
0004     C      *AL* IS THE LENGHT
0004            AL=1000.
000C            B=AL/5.75
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.3
0024            D=AL/14.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR STEEL
0030            POI=0.3
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR STEEL
0038            E=30.*10.**6
004C     C      *DST* IS THE DESIGN STRESS
004C            DST=18000.
0054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0054            S=30.
005C     C      *BM* IS THE BENDING MOMENT
005C            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
0088            G=0.30396*S*S*(1.-POI*POI)/E
0084     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
0084     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0084            TOP=5.12
008C            BOT=0.62
00C4            A=560.*BM*(B*BOT+D*TOP)
00F0            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
014C     C      *STH* IS THE STRESS ON TOP DUE TO HOGGING
014C            STH=A/DEN
0158            WRITE(5,60)STH
0174       60 FORMAT(' ',20X,'STH='F10.3)
018E            C=560.*BM*(B*TOP+D*TOP)
01B4     C      *SBH* IS THE STRESS ON BOT DUE TO HOGGING
01BA            SBH=C/DEN
01C6            WRITE(5,90)SBH
01E2       90 FORMAT(' ',20X,'SBH='F10.3)
01FC     C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
01FC            SBCRIT=BOT*BOT/G
020C            WRITE(5,110)SBCRIT
0228      110 FORMAT(' ',17X,'SBCRIT='F10.3)
0244            P=2.*D+TOP+B*(TOP+BOT)
0268     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
0268            DITOP=D*(B*BOT+D*TOP)/P
028C            WRITE(5,40)DITOP
02A8       40 FORMAT(' ',18X,'DITOP='F10.4)
02C4     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
02C4            DIBOT=D*(B*TOP+D*TOP)/P
02E8            WRITE(5,50)DIBOT
0324       50 FORMAT(' ',18X,'DIBOT='F10.4)
0320            END
```

```
0?(S) .U      0324(V) AL      032C(V) B       0334(V) DRA     033C(V) D
**(V) POI     034C(V) E       0000(S) .R      035C(V) DST     0364(V) S
5?(V) BM      037C(V) G       0388(V) TOP     03?0(V) BOT     0398(V) A
4?(V) DEN     03BC(V) STH     0174(L) 60      0000(S) ?I      03C0(V) C
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
:4(V) SaH     01E2(L) 90      03C8(V) SBCRIT  0228(L) 110     03CC(V) P
)0(V) DITOP   02A8(L) 40      03D4(V) DIBOT   0304(L) 50      0000(S) .V
 .EQ         L
)F


ROGRAM LABELS:
2070 *MAIN*   2A68 .V        2898 .COMP      2A76 @I         2448 .R         2960 .Z
288E $6       2488 .A        298C .MES       283A .W         2642 EXP        27C8 AI
253A ALOG     2900 .RARG     295C .5         2642 AEXP       2964 .ERCNT     2932 $8
2964 .0       2A3A .U        3B92

TRY-POINTS:
2448 .R       2488 .A        253A ALOG       2642 AEXP       2642 EXP        27C8 AI
283A .W       2898 .COMP     28BE $6         2900 .RARG      2932 $8         295C .5
2960 .ZERO    2964 .ERCNT    2966 .0         298C .MES       2A46 .U         2A6C .V
2A76 @I

MMON-BLOCKS:
)E


EFINED SUBROUTINES:
)E


ANSFER ADDRESS 2070
CUTION BEGINS:

                STH= 18085.023
                SBH= 47973.711
             SBCRIT= 46323.625
              DITOP=   19.5551
              DIBOT=   51.8734
END


F VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74


JOB HANDLING CHARGE    $  .35 / JOB        .35
 85 LINES PRINTED PR1  $ 1.25 / K LN       .11
 54 CARDS READ         $ 1.50 / K CD       .08
 00 PLOTTER VECTORS    $  .25 / 1000       .00
 13 MODEL 70 SECONDS   $25.00 / HOUR       .09
 00 MODEL 80 SECONDS   $12.50 / HOUR       .00
                    TOTAL CHARGE $         .63


REIR 490 14731  LOGGED OUT 05/06/74 17:36.  $   8.11 LEFT AFTER    05 LOGINS.
```

SUMMARY

Length	= 1000 ft
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 30"
Material	- STEEL
TOP	= 5.12"
BOT	= 0.62"
STH	= 18085.02
SBH	= 47973.71
SBCRIT	= 46323.82
DITOP	= 19.55'
DIBOT	= 51.87'

We might say here that the value chosen for S is small and this accounts for the compression at the bottom to reach such a high value.

In the next case, the value chosen for S is increased to 60 inches.

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
2004     C      *AL* IS THE LENGHT
2004            AL=1000.
200C            B=AL/5.75
2018     C      *DRA* IS THE DRAFT
2018            DRA=B/3.3
2024            D=AL/14.
2030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
2030     C      FOR STEEL
2030            POI=0.3
2038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
2038     C      FOR STEEL
2038            E=30.*10.**6
204C     C      *DST* IS THE DESIGN STRESS
204C            DST=18000.
2054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
2054            S=60.
205C     C      *BM* IS THE BENDING MOMENT
205C            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
2068            G=0.30396*S*S*(1.-POI*POI)/E
2074            A=9.*B*B*D/(140.*BM)
207C            C=3.*B*C*D/(70.*BM)
2094            F=3.*D*D*D/(140.*BM)
20AC     C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
20AC            WRITE(5,10)
20B2        10  FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
20CE     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
20CE     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
20CE            BOT1=0.02
20D6        11  TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
20EE            WRITE(5,20)TOP1,BOT1
20F2        20  FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
2102            BOT1=BOT1+0.02
2116            IF(BOT1.GT.2.)GO TO 30
2128            GO TO 11
212C        30  TOP2=1.
2134        31  BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
2148            WRITE(5,40)TOP2,BOT2
2154        40  FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
215C            TOP2=TOP2+0.2
2168            IF(TOP2.GT.6. ) GO TO 50
217A            GO TO 31
217E        50  CONTINUE
217E     C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
217E            WRITE(5,60)
2192        60  FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
21A0            BOT3=0.4
21A8        61  TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
21B4            WRITE(5,70)TOP3,BOT3
21B8        70  FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
21E0            BOT3=BOT3+0.02
21EC            IF(BOT3.GT..85)GO TO 80
21FE        80  TOP4=1.
```

```
2406        81 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
244A           WRITE(5,90)TOP4,BOT4
246E        90 FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4=',F9.4)
2496           TOP4=TOP4+0.2
24A2           IF(TOP4.GT.5.5)GO TO 100
24B4           GO TO 81
24B8       100 CONTINUE
24B8           END
```

```
(S) .U      04BC(V) AL      04C4(V) B       04CC(V) DRA     04D4(V) D
C(V) POI    04E4(V) E       0000(S) .R      04F4(V) DST     04FC(V) S
(V) BM      0518(V) G       0524(V) A       0530(V) C       053C(V) F
(L) 10      0000(S) @I      0540(V) BOT1    0176(L) 11      0548(V) TOP1
(L) 20      022C(L) 30      0558(V) TOP2    0234(L) 31      055C(V) BOT2
(L) 40      02FE(L) 50      0312(L) 60      0574(V) BOT3    0348(L) 61
C(V) TOP3   0388(L) 70      03FE(L) 80      0584(V) TOP4    0406(L) 81
(V) BOT4    046E(L) 90      0488(L) 100     0000(S) .V
EO          L
F
```

```
GRAM LABELS:
2270 *MAIN*   2C20 .V      2A50 .COMP    2C2E @I       2600 .R       2B18 .7
2A76 $6       2640 .A      2B74 .MES     29F2 .W       27FA EXP      2980 AI
26F2 ALOG     2AB8 .RARG   2B14 .5       27FA ^EXP     2B1C .ERCNT   2AEA $8
2B1C .0       2BF2 .U      3D4A
```

```
RY-POINTS:
2600 .R       2640 .A      26F2 ALOG     27FA ^EXP     27FA EXP      2980 AI
29F2 .W       2A50 .COMP   2A76 $6      2AB8 .RARG    2AEA $8       2B14 .5
2B18 .ZERO    2B1C .ERCNT  2B1E .0      2B74 .MES     2BFE .U       2C24 .V
2C2E @I
```

```
MON-BLOCKS:
E
```

```
EFINED SUBROUTINES:
E
```

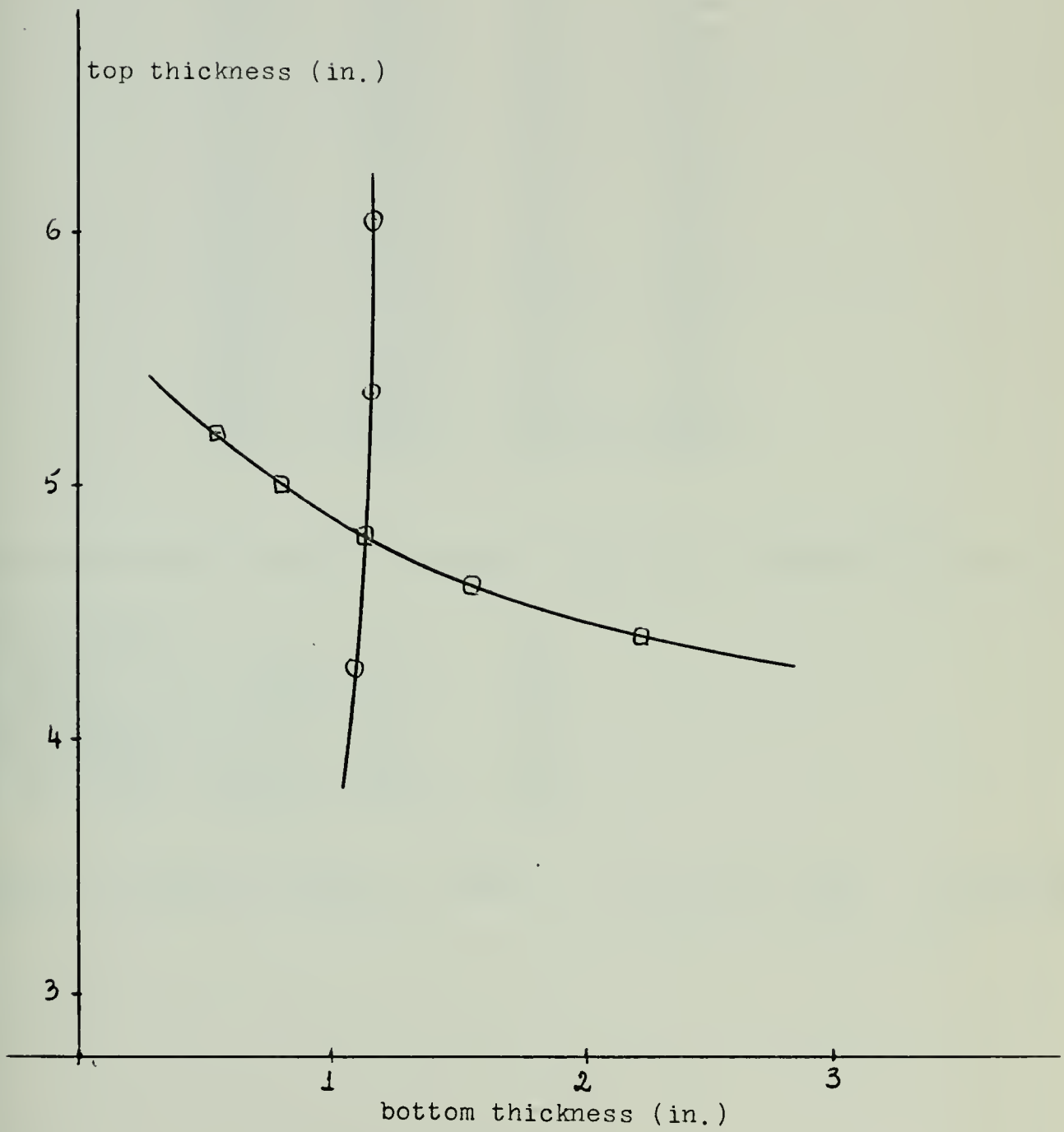
```
NSFER ADDRESS 2270
UTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0000	BOT1=	0.0200
TOP1=	0.0001	BOT1=	0.0400
TOP1=	0.0003	BOT1=	0.0600
TOP1=	0.0006	BOT1=	0.0800
TOP1=	0.0012	BOT1=	0.1000
TOP1=	0.0021	BOT1=	0.1200
TOP1=	0.0033	BOT1=	0.1400
TOP1=	0.0049	BOT1=	0.1600
TOP1=	0.0070	BOT1=	0.1800
TOP1=	0.0097	BOT1=	0.2000
TOP1=	0.0129	BOT1=	0.2200
TOP1=	0.0169	BOT1=	0.2400
TOP1=	0.0216	BOT1=	0.2600
TOP1=	0.0271	BOT1=	0.2800
TOP1=	0.0335	BOT1=	0.3000
TOP1=	0.0409	BOT1=	0.3200
TOP1=	0.0494	BOT1=	0.3400
TOP1=	0.0591	BOT1=	0.3600
TOP1=	0.0700	BOT1=	0.3800
TOP1=	0.0824	BOT1=	0.4000
TOP1=	0.0962	BOT1=	0.4200
TOP1=	0.1116	BOT1=	0.4400
TOP1=	0.1288	BOT1=	0.4600
TOP1=	0.1478	BOT1=	0.4800
TOP1=	0.1689	BOT1=	0.5000
TOP1=	0.1921	BOT1=	0.5200
TOP1=	0.2178	BOT1=	0.5400
TOP1=	0.2459	BOT1=	0.5600
TOP1=	0.2769	BOT1=	0.5800
TOP1=	0.3108	BOT1=	0.6000
TOP1=	0.3479	BOT1=	0.6200
TOP1=	0.3886	BOT1=	0.6400
TOP1=	0.4330	BOT1=	0.6600
TOP1=	0.4816	BOT1=	0.6800
TOP1=	0.5346	BOT1=	0.7000
TOP1=	0.5925	BOT1=	0.7200
TOP1=	0.6558	BOT1=	0.7400
TOP1=	0.7248	BOT1=	0.7600
TOP1=	0.8003	BOT1=	0.7800
TOP1=	0.8828	BOT1=	0.8000
TOP1=	0.9730	BOT1=	0.8200
TOP1=	1.0717	BOT1=	0.8400
TOP1=	1.1799	BOT1=	0.8600
TOP1=	1.2985	BOT1=	0.8800
TOP1=	1.4289	BOT1=	0.9000
TOP1=	1.5724	BOT1=	0.9200
TOP1=	1.7306	BOT1=	0.9400
TOP1=	1.9054	BOT1=	0.9600
TOP1=	2.0990	BOT1=	0.9800
TOP1=	2.3141	BOT1=	1.0000
TOP1=	2.5537	BOT1=	1.0200
TOP1=	2.8218	BOT1=	1.0400
TOP1=	3.1229	BOT1=	1.0600
TOP1=	3.4626	BOT1=	1.0800
TOP1=	3.8480	BOT1=	1.1000

TOP1= 4.2878	BOT1= 1.1200
TOP1= 4.7931	BOT1= 1.1400
TOP1= 5.3786	BOT1= 1.1600
TOP1= 6.0632	BOT1= 1.1800
TOP1= 6.8726	BOT1= 1.2000
TOP1= 7.8419	BOT1= 1.2200
TOP1= 9.0212	BOT1= 1.2400
TOP1= 10.4833	BOT1= 1.2600
TOP1= 12.3398	BOT1= 1.2800
TOP1= 14.7689	BOT1= 1.3000
TOP1= 18.0762	BOT1= 1.3200
TOP1= 22.8310	BOT1= 1.3400
TOP1= 30.2304	BOT1= 1.3600
TOP1= 43.2943	BOT1= 1.3800
TOP1= 72.4639	BOT1= 1.4000
TOP1= 194.7422	BOT1= 1.4200
TOP1=-339.7143	BOT1= 1.4400
TOP1= -95.4322	BOT1= 1.4600
TOP1= -57.1133	BOT1= 1.4800
TOP1= -41.5440	BOT1= 1.5000
TOP1= -33.1158	BOT1= 1.5200
TOP1= -27.8412	BOT1= 1.5400
TOP1= -24.2356	BOT1= 1.5600
TOP1= -21.6199	BOT1= 1.5800
TOP1= -19.6394	BOT1= 1.6000
TOP1= -18.0908	BOT1= 1.6200
TOP1= -16.8492	BOT1= 1.6400
TOP1= -15.8337	BOT1= 1.6600
TOP1= -14.9894	BOT1= 1.6800
TOP1= -14.2780	BOT1= 1.7000
TOP1= -13.6717	BOT1= 1.7200
TOP1= -13.1500	BOT1= 1.7400
TOP1= -12.6974	BOT1= 1.7600
TOP1= -12.3021	BOT1= 1.7800
TOP1= -11.9546	BOT1= 1.8000
TOP1= -11.6475	BOT1= 1.8200
TOP1= -11.3750	BOT1= 1.8400
TOP1= -11.1322	BOT1= 1.8600
TOP1= -10.9151	BOT1= 1.8800
TOP1= -10.7203	BOT1= 1.9000
TOP1= -10.5453	BOT1= 1.9200
TOP1= -10.3875	BOT1= 1.9400
TOP1= -10.2452	BOT1= 1.9600
TOP1= -10.1165	BOT1= 1.9800
TOP1= -10.0001	BOT1= 2.0000
TOP2= 1.0000	BOT2= -0.4673
TOP2= 1.2000	BOT2= -0.5810
TOP2= 1.4000	BOT2= -0.7055
TOP2= 1.6000	BOT2= -0.8440
TOP2= 1.8000	BOT2= -1.0009
TOP2= 2.0000	BOT2= -1.1829
TOP2= 2.2000	BOT2= -1.4002
TOP2= 2.4000	BOT2= -1.6693
TOP2= 2.6000	BOT2= -2.0190
TOP2= 2.8000	BOT2= -2.5045
TOP2= 3.0000	BOT2= -3.2460

TOP2=	3.2000	BOT2=	-4.5652
TOP2=	3.4000	BOT2=	-7.7108
TOP2=	3.6000	BOT2=	-26.8087
TOP2=	3.8000	BOT2=	16.3226
TOP2=	4.0000	BOT2=	5.8811
TOP2=	4.2000	BOT2=	3.3945
TOP2=	4.4000	BOT2=	2.2560
TOP2=	4.6000	BOT2=	1.5888
TOP2=	4.8000	BOT2=	1.1408
TOP2=	5.0000	BOT2=	0.8127
TOP2=	5.2000	BOT2=	0.5572
TOP2=	5.4000	BOT2=	0.3490
TOP2=	5.6000	BO·2=	0.1733
TOP2=	5.8000	BOT2=	0.0210
TOP2=	6.0000	BOT2=	-0.1140


top thickness (in.)
6
5
4
3
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.0182      BOT3=   0.4000
TOP4=   1.2000      BOT4=  16.1639
TOP4=   1.2000      BOT4=  15.3920
TOP4=   1.4000      BOT4=  14.6201
TOP4=   1.6000      BOT4=  13.8482
TOP4=   1.8000      BOT4=  13.0763
TOP4=   2.0000      BOT4=  12.3044
TOP4=   2.2000      BOT4=  11.5324
TOP4=   2.4000      BOT4=  10.7605
TOP4=   2.6000      BOT4=   9.9886
TOP4=   2.8000      BOT4=   9.2167
TOP4=   3.0000      BOT4=   8.4448
TOP4=   3.2000      BOT4=   7.6729
TOP4=   3.4000      BOT4=   6.9010
TOP4=   3.6000      BOT4=   6.1290
TOP4=   3.8000      BOT4=   5.3571
TOP4=   4.0000      BOT4=   4.5852
TOP4=   4.2000      BOT4=   3.8133
TOP4=   4.4000      BOT4=   3.0414
TOP4=   4.6000      BOT4=   2.2695
TOP4=   4.8000      BOT4=   1.4975
TOP4=   5.0002      BOT4=   0.7256
TOP4=   5.2000      BOT4=  -0.0463
TOP4=   5.4000      BOT4=  -0.8182
END

 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

J08 HANDLING CHARGE    $  .35 / JOB          .35
946 LINES PRINTED PR1  $ 1.25 / K LN         .31
 66 CARDS READ         $ 1.50 / K CD         .10
 88 PLOTTER VECTORS    $  .25 / 1000         .00
 17 MODEL 75 SECONDS   $25.00 / HOUR         .12
 00 MODEL 80 SECONDS   $12.50 / HOUR         .00
                 TOTAL CHARGE $              .88

PEIR 490 14731  LOGGED OUT 05/06/74 17:28.  $   8.74 LEFT AFTER    24 LOGINS.
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
0A     C      *AL* IS THE LENGHT
04           AL=1000.
2C           B=AL/5.75
18     C      *DRA* IS THE DRAFT
18           DRA=B/3.3
24           D=AL/14.
30     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
30     C      FOR STEEL
30           POI=0.3
38     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
38     C      FOR STEEL
38           E=30.*12.**6
4C     C      *DST* IS THE DESIGN STRESS
4C           DST=18000.
54     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
54           S=60.
5C     C      *BM* IS THE BENDING MOMENT
5C           BM=(B*DRA*AL*AL*0.75)/(35.*35.)
68           G=0.30396*S*S*(1.-POI*POI)/E
84     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
84     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
84           TOP=4.79
8C           BOT=1.15
C4           A=560.*BM*(B*BOT+D*TOP)
F8           DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
4C     C      *STH* IS THE STRESS ON TOP DUE TO HOGGING
4C           STH=A/DEN
58           WRITE(5,60)STH
74        60 FORMAT(' ',20X,'STH=',F10.3)
8E           C=560.*BM*(B*TOP+D*TOP)
8A     C      *SBH* IS THE STRESS ON BOT DUE TO HOGGING
8A           SBH=C/DEN
C6           WRITE(5,90)SBH
E2        90 FORMAT(' ',20X,'SBH=',F10.3)
FC     C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
FC           SBCRIT=BOT*BOT/G
2C           WRITE(5,110)SBCRIT
28       110 FORMAT(' ',17X,'SBCRIT=',F10.3)
44           P=2.*D*TOP+B*(TOP+BOT)
68     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
68           DITOP=D*(B*BOT+D*TOP)/P
6C           WRITE(5,40)DITOP
8A        40 FORMAT(' ',18X,'DITOP=',F10.4)
C4     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
C4           DIBOT=D*(B*TOP+D*TOP)/P
E8           WRITE(5,50)DIBOT
04        50 FORMAT(' ',18X,'DIBOT=',F10.4)
22           END
```

```
(S) .U      0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
[V] POI     034C[V] E       0000[S] .R      035C[V] DST     0364[V] S
[V] BM      0382[V] G       038C[V] TOP     0394[V] BOT     039C[V] A
[V] DEN     03C0[V] STH     0174[L] 60      0000[S] @I      03C4[V] C
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
:8(V) SRH      01E2(L) 90      03CC(V) SBCRIT  0228(L) 110     03D0(V) P
)4(V) DITOP    02A8(L) 40      03D8(V) DIBOT   0304(L) 50      0000(S  .V
.XEO          L
)F


ROGRAM LABELS:
2070 *MAIN*   2A6C .V       289C .COMP     2A7A .I       244C .R       2964 .Z
28C2 $6       248C .A       29C0 .MES      283E .W       2646 EXP      27CC AI
253E ALOG     2904 .RARG    2960 .5        2646 .EXP     2968 .ERCNT   2936 $8
2968 .0       2A3E .U       3896


NTRY-POINTS:
244C .R       248C .A       253E ALOG      2646 .EXP     2646 EXP      27CC AI
283E .W       289C .COMP    28C2 $6        2904 .RARG    2936 $8       2960 .5
2964 .ZERO    2968 .ERCNT   296A .0        29C0 .MES     2A4A .U       2A70 .V
2A7A .I


COMMON-BLOCKS:
NE


DEFINED SUBROUTINES:
NE


RANSFER ADDRESS 2070
ECUTION BEGINS:

              STH= 18017.242
              SBH= 39055.434
           SBCRIT= 39843.250
            DITOP=   22.5492
            DIBOT=   48.8793
END


F VIO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74


JOB HANDLING CHARGE     $  .35 / JOB          .35
85 LINES PRINTED PR1    $ 1.25 / K LN         .11
54 CARDS READ           $ 1.50 / K CD         .08
00 PLOTTER VECTORS      $  .25 / 100          .00
13 MODEL 70 SECONDS     $25.00 / HOUR         .09
00 MODEL 80 SECONDS     $12.50 / HOUR         .00
                    TOTAL CHARGE $            .63


EIR 490 14731  LOGGED OUT 05/06/74 17:37.  $   7.48 LEFT AFTER    26 LOGINS.
```

SUMMARY

Length	= 1000'
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 60"
Material	- STEEL
TOP	= 4.79"
BOT	= 1.15"
STH	= 18017.24
SBH	= 39055.43
SBCRIT	= 39843.44
DITOP	= 22.55'
DIBOT	= 48.88'

Since sometimes it is desirable to use aluminum alloys in the structure of ships, due to their light weight, high corrosion resistance and non-magnetic characteristics, in the following runs, the material considered is aluminum. The necessary change is made in the input to account for the properties of this material.

When considering aluminum as the structural material, we must keep in mind that the aluminum hull will be more flexible than a corresponding steel ship. The modulus of elasticity of aluminum is about one third that of steel, and if scantlings were identical, the deflection of an aluminum ship, under a given load, would be three times those of a steel ship.

However, to obtain a factor of safety on ultimate strength equal to that in steel, the area of an aluminum member in direct stress, or the section modulus of an aluminum member in bending would be about 1.5 times that of the corresponding steel member (based on an ultimate strength of about 60000 psi in medium steel and of about 40000 psi across the welds of a welded aluminum structure).

A section modulus of 1.5 times that in steel, with the same depth being considered in both cases, would result in a deflection in aluminum about twice that in steel. However, the lower modulus of elasticity of aluminum reduces its ability to resist buckling , and for the same factor of safety both the section modulus and the moment of inertia in aluminum would in

general be somewhat more than 1.5 times those in steel, so that the deflection of the aluminum structure would in general be somewhat less than twice that of the steel structure.

The greater deflection would reduce the natural frequency of hull vibration, and sowould affect the interaction of slamming stress and bending moment stress. It could also affect shaft bearing pressures. It has been proposed as an arbitrary basis of design that aluminum ships be designed for a deflection about 1.5 times that of steel ships. This would require a moment of inertia of twice the value of that in the steel hull girder, and would automatically result in a section modulus substantially more than 1.5 times that in steel, and a factor of safety correspondingly greater than in steel.

```
0004     C      *AL* IS THE LENGHT
0004           AL=1000.
000C           B=AL/5.75
0018     C      *DRA* IS THE DRAFT
0018           DRA=B/3.3
0024           D=AL/14.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR ALUMINUM
0032           POI=0.33
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR ALUMINUM
0038           E=10.*10.**6
004C     C      *DST* IS THE DESIGN STRESS
004C           DST=18000.
0054     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0054           S=10.
005C     C      *BM* IS THE BENDING MOMENT
005C           BM=(B*DRA*AL*AL*0.75)/(35.*35.)
0068           G=0.3025*S*S*(1.-POI*POI)/E
0074           A=9.*B**3*D/(140.*BM)
00CC           C=3.*B*B*D/(70.*BM)
0124           E=3.*D*B*D/(140.*BM)
012C     C      THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
012C           WRITE(5,10)
0140     10    FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
016E     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
016E     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
016E           BOT1=0.2
0176     11    TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
019E           WRITE(5,20)TOP1,BOT1
01E2     20    FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
01FA           BOT1=BOT1+0.01
0216           IF(BOT1.GT.0.4)GO TO 30
0228           GO TO 11
022C     30    TOP2=1.
0234     31    BOT2=TOP2*(12.*D-(C+E)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
0298           WRITE(5,40)TOP2,BOT2
02B4     40    FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
02DC           TOP2=TOP2+0.2
02E8           IF(TOP2.GT.5. ) GO TO 50
02FA           GO TO 31
02FE     50    CONTINUE
02FE     C      THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
02FE           WRITE(5,60)
0312     60    FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
0342           BOT3=0.1
034B     61    TOP3=((C+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
0394           WRITE(5,70)TOP3,BOT3
03B8     70    FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
03E0           BOT3=BOT3+0.01
03EC           IF(BOT3.GT..24)GO TO 80
03FE           GO TO 61
```

```
2402        90  TOP4=1.
240A        91  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
241E            WRITE(5,90)TOP4,BOT4
2472        92  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
249A            TOP4=TOP4+0.2
24AE            IF(TOP4.GT.5.5)GO TO 100
24BB            GO TO 81
24BC        10  CONTINUE
24EC            END
```

```
0 (S) .U        24C0[V] AL      24C8[V] B       24D0[V] DRA     0408[V] D
E (V) 90I       24E8[V] E       2400[C] .R      04F4[V] DST     04FC[V] S
2 (V) 9         2514[V] G       2520[V] A       052C[V] C       0538[V] F
4 (L) 10        2720[S] 9I      253C[V] BOT1    0176[L] 11      0544[V] TOP1
6 (L) 20        222C[L] 30      2560[V] TOP2    0234[L] 31      055C[V] BOT2
8 (L) 40        22FE[L] 50      2312[L] 60      0570[V] BOT3    0348[L] 61
7 (V) TOP3      2335[L] 70      2402[L] 80      0580[V] TOP4    040A[L] 81
A (V) BOT4      2472[L] 90      24BC[L] 100     0003[S] .V
  EC          L
0
```

```
F GRAM LABELS:
2270 **ALL*     2C1C .V         2A4C .COMP      2C2A AI         25FC .R         2B14 .7
2A72 $4         263C .A         2B70 .MES       29EF .W         27F6 EXP        297C AI
26FE ALOG       2AB4 .RARG      2B10 .5         27F6 AEXP       2B18 .ERCNT     2AE6 $8
2B1A .0         2BEE .U         3D46

ARY-POINTS:
25FC .R         263C .A         26EF ALOG       27F6 AEXP       27F6 EXP        297C AI
29EF .W         2A4C .COMP      2A72 $4         2AB4 .RARG      2AE6 $8         2B10 .5
2B14 .7FF0      2B18 .ERCNT     2B1A .0         2B70 .MES       2BFA .U         2C20 .V
2C2A 91

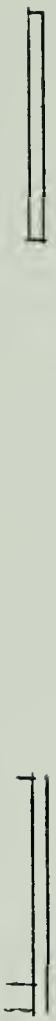
O NON-BLOCKS:
0 E

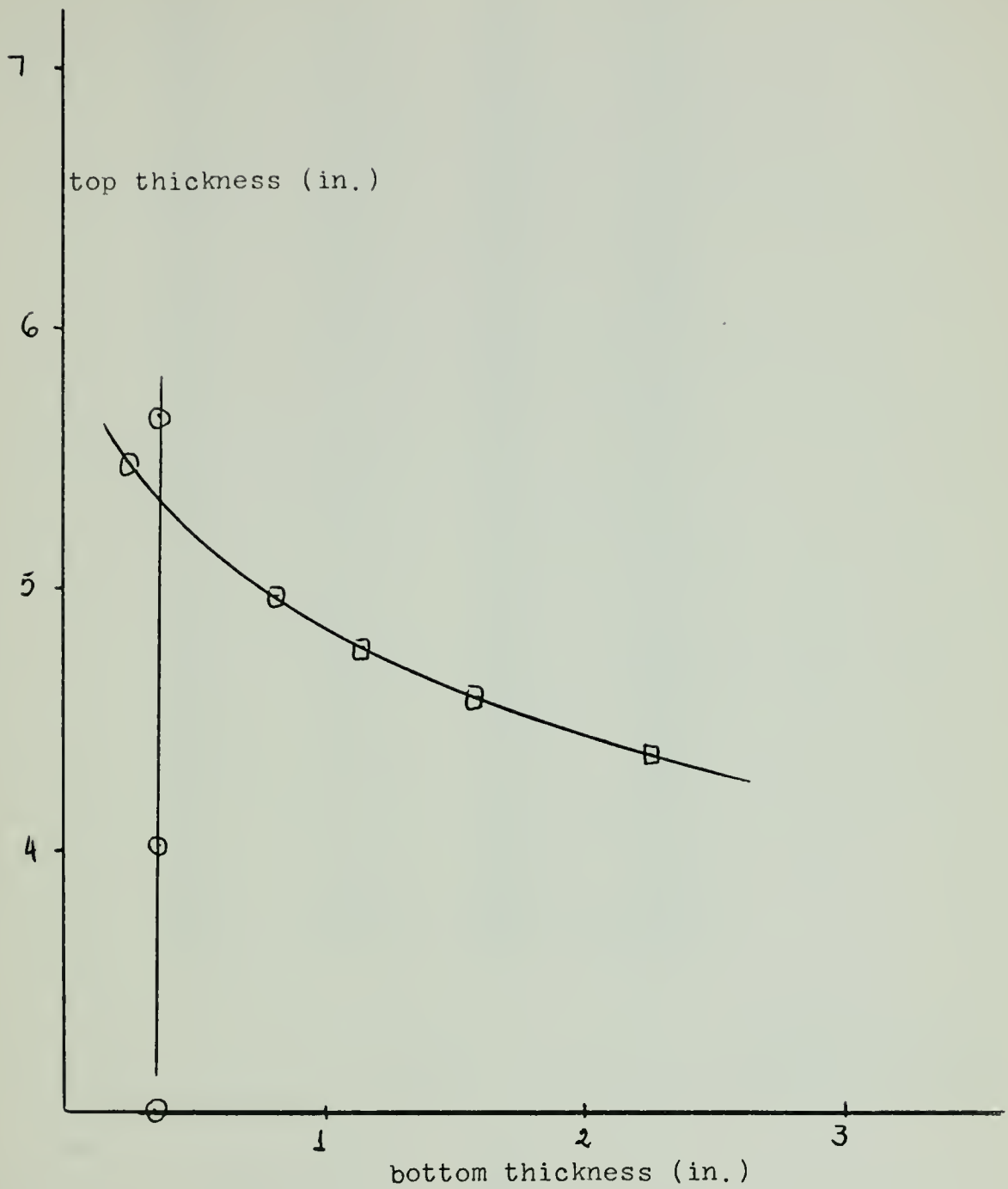
N EFINED SUBROUTINES:
0 E

RANSFER ADDRESS 2270
ECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.1528	BOT1=	0.2000
TOP1=	0.1828	BOT1=	0.2100
TOP1=	0.2177	BOT1=	0.2200
TOP1=	0.2596	BOT1=	0.2300
TOP1=	0.3124	BOT1=	0.2400
TOP1=	0.3624	BOT1=	0.2500
TOP1=	0.4285	BOT1=	0.2600
TOP1=	0.5128	BOT1=	0.2700
TOP1=	0.6 21	BOT1=	0.2800
TOP1=	0.7123	BOT1=	0.2900
TOP1=	0.8487	BOT1=	0.3000
TOP1=	1.0164	BOT1=	0.3100
TOP1=	1.2263	BOT1=	0.3200
TOP1=	1.4941	BOT1=	0.3300
TOP1=	1.8456	BOT1=	0.3400
TOP1=	2.3218	BOT1=	0.3500
TOP1=	3.0 3	BOT1=	0.3600
TOP1=	4.0363	BOT1=	0.3700
TOP1=	5.7921	BOT1=	0.3800
TOP1=	9.4016	BOT1=	0.3900
TOP1=	20.8821	BOT1=	0.4000
TOP2=	1.0 0	BOT2=	-0.4673
TOP2=	1.2 0	BOT2=	-0.5810
TOP2=	1.4 0	BOT2=	-0.7055
TOP2=	1.6 0	BOT2=	-0.8440
TOP2=	1.8 0	BOT2=	-1.0009
TOP2=	2.0 0	BOT2=	-1.1829
TOP2=	2.2 0	BOT2=	-1.4002
TOP2=	2.4 0	BOT2=	-1.6693
TOP2=	2.6 0	BOT2=	-2.0190
TOP2=	2.8 0	BOT2=	-2.5045
TOP2=	3.0 0	BOT2=	-3.2460
TOP2=	3.2 0	BOT2=	-4.5652
TOP2=	3.4 0	BOT2=	-7.7108
TOP2=	3.6 0	BOT2=	-26.8087
TOP2=	3.8 0	BOT2=	16.3226
TOP2=	4.0 0	BOT2=	5.8811
TOP2=	4.2 0	BOT2=	3.3945
TOP2=	4.4 0	BOT2=	2.2560
TOP2=	4.6 0	BOT2=	1.5888
TOP2=	4.8 0	BOT2=	1.1408
TOP2=	5.0 0	BOT2=	0.8127
TOP 2=	5.5000	BOT 2=	0.2578




7
top thickness (in.)
6
5
4
1
2
3
bottom thickness (in.)

```
                BOTTOM ASSUMED LARGER THAN TOP
                TOP3=  -0.0191      BOT3=   0.1000
                TOP3=  -0.0267      BOT3=   0.1100
                TOP3=   0.0007      BOT3=   0.1200
                TOP3=   0.0182      BOT3=   0.1300
                TOP3=   0.0269      BOT3=   0.1400
                TOP3=   0.0360      BOT3=   0.1500
                TOP3=   0.0528      BOT3=   0.1600
                TOP3=   0.0723      BOT3=   0.1700
                TOP3=   0.0948      BOT3=   0.1800
                TOP3=   0.1204      BOT3=   0.1900
                TOP3=   0.1493      BOT3=   0.2000
                TOP3=   0.1817      BOT3=   0.2100
                TOP3=   0.2177      BOT3=   0.2200
                TOP3=   0.2576      BOT3=   0.2300
                TOP3=   0.3014      BOT3=   0.2400
                TOP4=   1.0000      BOT4=  16.1639
                TOP4=   1.2000      BOT4=  15.3920
                TOP4=   1.4000      BOT4=  14.6201
                TOP4=   1.6000      BOT4=  13.8482
                TOP4=   1.8000      BOT4=  13.0763
                TOP4=   2.0000      BOT4=  12.3044
                TOP4=   2.2000      BOT4=  11.5324
                TOP4=   2.4000      BOT4=  10.7605
                TOP4=   2.6000      BOT4=   9.9886
                TOP4=   2.8000      BOT4=   9.2167
                TOP4=   3.0000      BOT4=   8.4448
                TOP4=   3.2000      BOT4=   7.6729
                TOP4=   3.4000      BOT4=   6.9010
                TOP4=   3.6000      BOT4=   6.1290
                TOP4=   3.8000      BOT4=   5.3571
                TOP4=   4.0000      BOT4=   4.5852
                TOP4=   4.2000      BOT4=   3.8133
                TOP4=   4.4000      BOT4=   3.0414
                TOP4=   4.6000      BOT4=   2.2695
                TOP4=   4.8000      BOT4=   1.4975
                TOP4=   5.0000      BOT4=   0.7256
                TOP4=   5.2000      BOT4=  -0.0463
                TOP4=   5.4000      BOT4=  -0.8182
END

F VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74


JOB HANDLING CHARGE    $  .35 / JOB          .35
177 LINES PRINTED PR1  $ 1.25 / K LN         .22
 67 CARDS READ         $ 1.50 / K CD         .10
 00 PLOTTER VECTORS    $  .25 / 1000         .00
 00 MODEL 75 SECONDS   $25.00 / HOUR         .14
 00 MODEL 85 SECONDS   $12.50 / HOUR         .00
                  TOTAL CHARGE $            .81


EIR 402 14731  LOGGED OUT 05/06/74 19:37.  $   6.67 LEFT AFTER     07 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=100.
      C     D=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=A/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=10.
      C     *B* IS THE BENDING MOMENT
            B=(B*DRA*AL**2*.75)/(35.*35.)
            G=.3039A*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=5.35
            BOT=0.343
            A=56.*BM*(B*BOT+D*TOP)
            DEN=D*(3.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',25X,'STH='F10.3)
            C=56.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',25X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,47)DITOP
         47 FORMAT(' ',19X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,57)DIBOT
         57 FORMAT(' ',18X,'DIBOT='F10.4)
            END
 (S) .R       0324(V) AL       032C(V) B        0334(V) DRA      033C(V) D
 (V) POI      034C(V) E        0352(S) .R       0358(V) DST      0360(V) S
 (V) BM       0378(V) G        0384(V) TOP      038C(V) BOT      0394(V) A
 (V) DEN      03A8(V) STH      0174(L) 60       0000(S) @I       03BC(V) C
```

STRENGHT OF SHIPSTON THE NEUTRAL AXIS LOCATION PAGE 2

```
(V) SBM      ,1E2(L) 90      03C4(V) SBCRIT  0228(L) 110     03C8(V) P
(V) DITOP    2A8(L) 40       03D2(V) DIBOT   0304(L) 50      0000(S) .V
EO          L
```

```
GRAM LABELS:
V7W *MAIN*   2A64 .V        2594 .COMP     2A72 .I        2444 .R        295C .Z
SBA 36       2484 .A        2988 .MES      2936 .W        263E EXP       27C4 AI
536 ALOG     28EC .RARG     2958 .5        263E AEXP      2960 .ERCNT    292E $8
582 .C       2736 .U        3A8E
```

```
NX-POINTS:
444 .C       2484 .A        2536 ALOG      263E AEXP      263E EXP       27C4 AI
236 .I       2504 .COMP     28BA 36        28EC .RARG     292E $8        2958 .5
EC .ZERO     2961 .ERCNT    2963 .C        2988 .MES      2A42 .U        2A68 .V
A72 .W
```

```
NON-BLOCKS:
E
```

```
EFINED SUBROUTINES:
E
```

```
NSFER ADDRESS 2270
UTION BEGINS:

              STM= 18111.109
              SBM= 53387.000
           SBCRIT= 48640.414
            DITOP=   18.0932
            DIBOT=   53.3053
*D
```

```
 VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74

OB HANDLING CHARGE    $   .35 / JOB          .35
25 LINES PRINTED PR1  $ 1.25 / K LN          .11
54 CARDS READ         $ 1.50 / K CD          .08
00 PLOTTER VECTORS    $   .25 / 1000         .00
17 MODEL 75 SECONDS   $25.20 / HOUR          .12
00 MODEL 91 SECONDS   $12.50 / HOUR          .00
                   TOTAL CHARGE $            .66

EIP 402 14731  LOGGED OUT 25/06/74 19:56.  $   3.43 LEFT AFTER    31 LOGINS.
```

SUMMARY

Length	= 1000'
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 10"
Material	- ALUMINUM
TOP	= 5.35"
BOT	= 0.363"
STH	= 18111.11
SBH	= 53387.98
SBCRIT	= 48648.64
DITOP	= 18.09'
DIBOT	= 53.34'

```
C       *AL* IS THE LENGHT
        AL=100.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR ALUMINUM
        POI=0.33
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR ALUMINUM
        E=10.**10.**6
C       *DST* IS THE DESIGN STRESS
        DST=18000.
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=30.
C       *BM* IS THE BENDING MOMENT
        BM=(B*DRA*AL*AL*0.75)/(35.**35.)
        G=0.3C396*S*S*(1.-POI*POI)/E
        A=9.*B*B*D/(140.*BM)
        C=3.*B**D/(7.*BM)
        F=3.*D**D/(140.*BM)
C       THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
        WRITE(5,10)
   10   FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT1=0.2
   11   TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
        WRITE(5,20)TOP1,BOT1
   20   FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
        BOT1=BOT1+0.1
        IF(BOT1.GT.2.5)GO TO30
        GO TO 11
   30   TOP2=1.
   31   BOT2=TOP2*(12.*D-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
        WRITE(5,40)TOP2,BOT2
   40   FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
        TOP2=TOP2+0.2
        IF(TOP2.GT.6. ) GO TO 50
        GO TO 31
   50   CONTINUE
C       THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
        WRITE(5,60)
   60   FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
        BOT3=0.1
   61   TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
        WRITE(5,70)TOP3,BOT3
   70   FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
        BOT3=BOT3+0.01
        IF(BOT3.GT.1.5)GO TO 80
        GO TO 61
```

```
-42          90  TOP4=1.
-7A          31  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
-4E              WRITE(5,90)TOP4,BOT4
-72          90  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4=',F9.4)
-9A              TOP4=TOP4+0.2
-A6              IF(TOP4.GT.5.5)GO TO 100
-B3              GO TO 31
-BC          100 CONTINUE
-DC              END
```

(S) .U	04C4[V] AL	04C8[V] B	04D0[V] DRA	04D8[V] D			
(V) PDI	04E8[V] F	0000[C] .R	04F4[V] DST	04FC[V] S			
(V) SW	0518[V] G	0524[V] A	0534[V] C	053C[V] F			
(L) 10	0540[S] BI	0548[V] BOT1	0176[L] 11	0548[V] TOP1			
(L) 20	022C[L] 30	055C[V] TOP2	0234[L] 31	0560[V] BOT2			
(L) 40	02EE[L] 50	0312[L] 60	0574[V] BOT3	0348[L] 61			
(V) TOP3	034E[L] 70	04C2[L] 80	0584[V] TOP4	040A[L 81			
(V) BOT4	0472[L] 90	04DC[L] 100	0000[S] .V				

ENTRY POINTS:

2600 .R	2644 .A	26F2 ALOG	27FA AEXP	27FA EXP	2980 AIN		
9F2 .W	2A50 .COMP	2A76 $$	2ABE .RARG	2AEA $$	2B14 .S		
2B18 .ZERO	2B1C .ERCNT	2B1E .O	2B74 .MES	2BFE .U	2C24 .V		
2C2E .I							

NON-BLOCKS:

E

DEFINED SUBROUTINES:

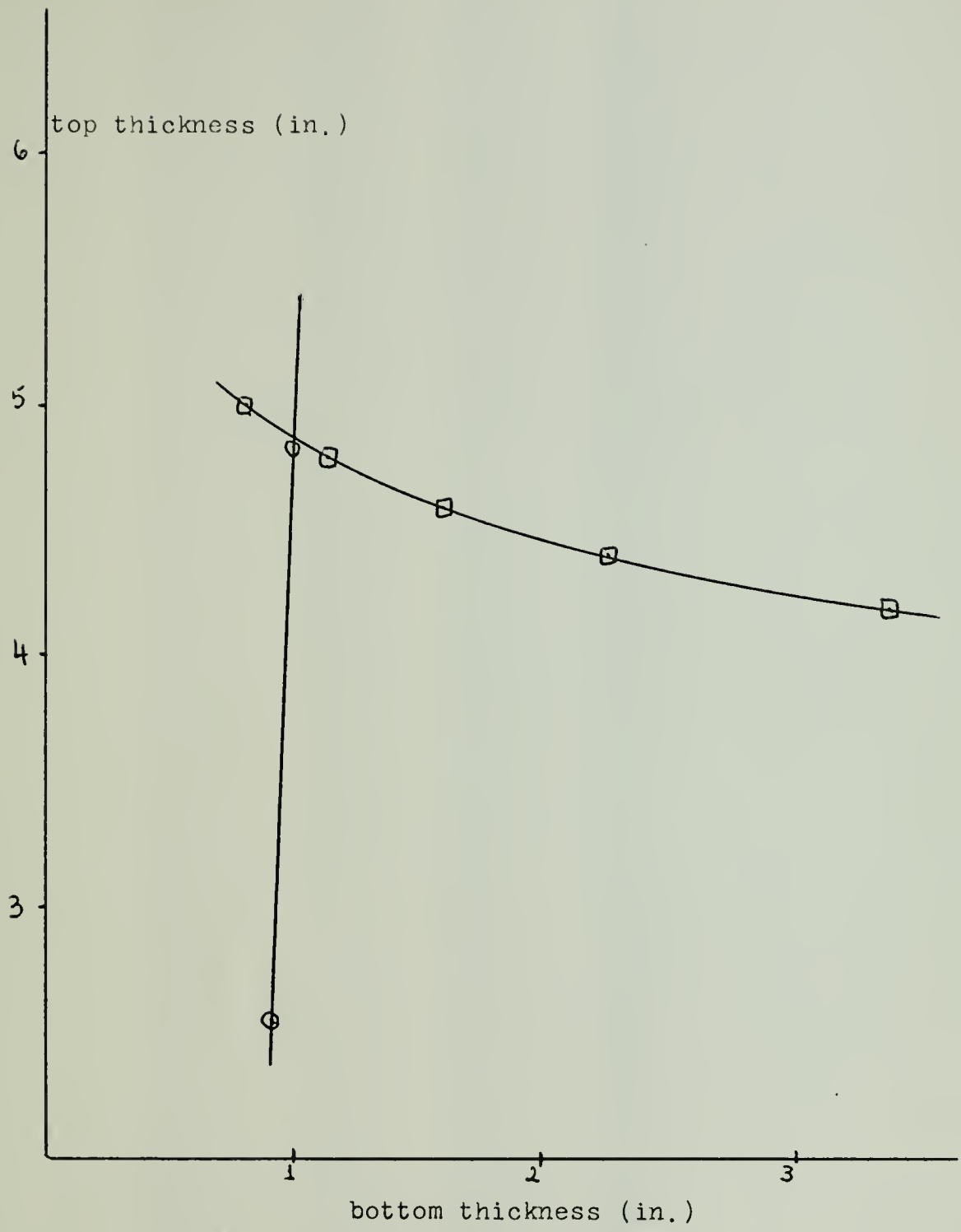
E

TRANSFER ADDRESS 2C78

EXECUTION BEGINS:

TOP ASSUMED LARGER THAN BOTTOM

TOP1=	0.0123	BOT1=	0.2000
TOP1=	0.0264	BOT1=	0.3000
TOP1=	0.0417	BOT1=	0.4000
TOP1=	0.0591	BOT1=	0.5000
TOP1=	0.0794	BOT1=	0.6000
TOP1=	0.1040	BOT1=	0.7000
TOP1=	0.1376	BOT1=	0.8000
TOP1=	0.1876	BOT1=	0.9000
TOP1=	0.2778	BOT1=	1.0000
TOP1=	0.4965	BOT1=	1.1000
TOP1=	0.9441	BOT1=	1.2000
TOP1=	2.0267	BOT1=	1.3000
TOP1=	4.7538	BOT1=	1.4000
TOP1=	7.0622	BOT1=	1.5000
TOP1=	9.4724	BOT1=	1.6000
TOP1=	11.8654	BOT1=	1.7000
TOP1=	14.1945	BOT1=	1.8000
TOP1=	16.4417	BOT1=	1.9000
TOP1=	18.6137	BOT1=	2.0000
TOP1=	20.7077	BOT1=	2.1000
TOP1=	22.7208	BOT1=	2.2000
TOP1=	24.6511	BOT1=	2.3000
TOP1=	26.4973	BOT1=	2.4000
TOP1=	28.2592	BOT1=	2.5000
TOP2=	1.0000	BOT2=	-0.4673
TOP2=	1.2000	BOT2=	-0.5810
TOP2=	1.4000	BOT2=	-0.7055
TOP2=	1.6000	BOT2=	-0.8440
TOP2=	1.8000	BOT2=	-1.0009
TOP2=	2.0000	BOT2=	-1.1829
TOP2=	2.2000	BOT2=	-1.4002
TOP2=	2.4000	BOT2=	-1.6693
TOP2=	2.6000	BOT2=	-2.0190
TOP2=	2.8000	BOT2=	-2.5045
TOP2=	3.0000	BOT2=	-3.2460
TOP2=	3.2000	BOT2=	-4.5652
TOP2=	3.4000	BOT2=	-7.7102
TOP2=	3.6000	BOT2=	-26.8087
TOP2=	3.8000	BOT2=	16.3226
TOP2=	4.0000	BOT2=	5.8811
TOP2=	4.2000	BOT2=	3.3945
TOP2=	4.4000	BOT2=	2.2560
TOP2=	4.6000	BOT2=	1.5888
TOP2=	4.8000	BOT2=	1.1408
TOP2=	5.0000	BOT2=	0.8127
TOP2=	5.2000	BOT2=	0.5572
TOP2=	5.4000	BOT2=	0.3490
TOP2=	5.6000	BOT2=	0.1733
TOP2=	5.8000	BOT2=	0.0210
TOP2=	6.0000	BOT2=	-0.1140


top thickness (in.)
6
5
4
3
1
2
3
bottom thickness (in.)

BOTTOM ASSUMED LARGER THAN TOP

TOP3=	-3.03x9	BOT3=	0.1000
TOP3=	-3.04x9	BOT3=	0.1100
TOP3=	-3.04x7	BOT3=	0.1200
TOP3=	-3.04x3	BOT3=	0.1300
TOP3=	-3.04x7	BOT3=	0.1400
TOP3=	-3.05x8	BOT3=	0.1500
TOP3=	-3.05x5	BOT3=	0.1600
TOP3=	-3.05x0	BOT3=	0.1700
TOP3=	-3.05x2	BOT3=	0.1800
TOP3=	-3.05x0	BOT3=	0.1900
TOP3=	-3.05x4	BOT3=	0.2000
TOP3=	-3.05x5	BOT3=	0.2100
TOP3=	-3.05x1	BOT3=	0.2200
TOP3=	-3.05x3	BOT3=	0.2300
TOP3=	-3.05x1	BOT3=	0.2400
TOP3=	-3.05x4	BOT3=	0.2500
TOP3=	-3.05x3	BOT3=	0.2600
TOP3=	-3.04x6	BOT3=	0.2700
TOP3=	-3.04x4	BOT3=	0.2800
TOP3=	-3.04x7	BOT3=	0.2900
TOP3=	-3.03x4	BOT3=	0.3000
TOP3=	-3.03x5	BOT3=	0.3100
TOP3=	-3.02x1	BOT3=	0.3200
TOP3=	-3.02x4	BOT3=	0.3300
TOP3=	-3.01x3	BOT3=	0.3400
TOP3=	-3.0.x9	BOT3=	0.3500
TOP3=	0.0x1	BOT3=	0.3600
TOP3=	0.01x9	BOT3=	0.3700
TOP3=	0.02x3	BOT3=	0.3800
TOP3=	0.03x5	BOT3=	0.3900
TOP3=	0.04x5	BOT3=	0.4000
TOP3=	0.05x2	BOT3=	0.4100
TOP3=	0.06x7	BOT3=	0.4200
TOP3=	0.07x0	BOT3=	0.4300
TOP3=	0.09x2	BOT3=	0.4400
TOP3=	0.10x1	BOT3=	0.4500
TOP3=	0.12x0	BOT3=	0.4600
TOP3=	0.14x8	BOT3=	0.4700
TOP3=	0.15x4	BOT3=	0.4800
TOP3=	0.17x0	BOT3=	0.4900
TOP3=	0.19x5	BOT3=	0.5000
TOP3=	0.21x0	BOT3=	0.5100
TOP3=	0.23x5	BOT3=	0.5200
TOP3=	0.25x0	BOT3=	0.5300
TOP3=	0.27x5	BOT3=	0.5400
TOP3=	0.30x0	BOT3=	0.5500
TOP3=	0.33x6	BOT3=	0.5600
TOP3=	0.36x3	BOT3=	0.5700
TOP3=	0.39x1	BOT3=	0.5800
TOP3=	0.41x0	BOT3=	0.5900
TOP3=	0.44x0	BOT3=	0.6000
TOP3=	0.47x2	BOT3=	0.6100
TOP3=	0.51x6	BOT3=	0.6200
TOP3=	0.54x1	BOT3=	0.6300
TOP3=	0.57x9	BOT3=	0.6400
TOP3=	0.61x9	BOT3=	0.6500

TOP3=	BOT3= 0.6600
TOP3=	BOT3= 0.6700
TOP3=	BOT3= 0.6800
TOP3=	BOT3= 0.6900
TOP3=	BOT3= 0.7000
TOP3=	BOT3= 0.7100
TOP3=	BOT3= 0.7200
TOP3=	BOT3= 0.7300
TOP3=	BOT3= 0.7400
TOP3=	BOT3= 0.7500
TOP3=	BOT3= 0.7600
TOP3=	BOT3= 0.7700
TOP3=	BOT3= 0.7800
TOP3=	BOT3= 0.7900
TOP3=	BOT3= 0.8000
TOP3=	BOT3= 0.8100
TOP3=	BOT3= 0.8200
TOP3=	BOT3= 0.8300
TOP3=	BOT3= 0.8400
TOP3=	BOT3= 0.8500
TOP3=	BOT3= 0.8600
TOP3=	BOT3= 0.8700
TOP3=	BOT3= 0.8800
TOP3=	BOT3= 0.8900
TOP3=	BOT3= 0.9000
TOP3=	BOT3= 0.9100
TOP3= 2.1256	BO 3= 0.9200
TOP3=	BOT3= 0.9300
TOP3=	BOT3= 0.9400
TOP3=	BOT3= 0.9500
TOP3=	BOT3= 0.9600
TOP3=	BOT3= 0.9700
TOP3=	BO 3= 0.9800
TOP3=	BOT3= 0.9900
TOP3=	BOT3= 1.0000
TOP3=	BOT3= 1.0100
TOP3=	BOT3= 1.0200
TOP3=	BOT3= 1.0300
TOP3=	BOT3= 1.0400
TOP3=	BOT3= 1.0500
TOP3=	BOT3= 1.0600
TOP3=	BOT3= 1.0700
TOP3=	BOT3= 1.0800
TOP3=	BOT3= 1.0900
TOP3=	BOT3= 1.1000
TOP3=	BOT3= 1.1100
TOP3=	BOT3= 1.1200
TOP3=	BOT3= 1.1300
TOP3=	BOT3= 1.1400
TOP3=	BOT3= 1.1500
TOP3=	BOT3= 1.1600
TOP3=	BOT3= 1.1700
TOP3=	BOT3= 1.1800
TOP3=	BOT3= 1.1900
TOP3=	BOT3= 1.2000
TOP3=	BOT3= 1.2100
TOP3= 5.3346	BOT3= 1.2200

TOP3=	5.4772	BOT3=	1.2300
TOP3=	5.6292	BOT3=	1.2400
TOP3=	5.7856	BOT3=	1.2500
TOP3=	5.9134	BOT3=	1.2600
TOP3=	6.2636	BOT3=	1.2700
TOP3=	6.3163	BOT3=	1.2800
TOP3=	6.3714	BOT3=	1.2900
TOP3=	6.5280	BOT3=	1.3000
TOP3=	6.6882	BOT3=	1.3100
TOP3=	6.8518	BOT3=	1.3200
TOP3=	7.0170	BOT3=	1.3300
TOP3=	7.1848	BOT3=	1.3400
TOP3=	7.3552	BOT3=	1.3500
TOP3=	7.5281	BOT3=	1.3600
TOP3=	7.7037	BOT3=	1.3700
TOP3=	7.8819	BOT3=	1.3800
TOP3=	8.0628	BOT3=	1.3900
TOP3=	8.2464	BOT3=	1.4000
TOP3=	8.4326	BOT3=	1.4100
TOP3=	8.6216	BOT3=	1.4200
TOP3=	8.8133	BOT3=	1.4300
TOP3=	9.0078	BOT3=	1.4400
TOP3=	9.2051	BOT3=	1.4500
TOP3=	9.4051	BOT3=	1.4600
TOP3=	9.6080	BOT3=	1.4700
TOP3=	9.8137	BOT3=	1.4800
TOP3=	10.0223	BOT3=	1.4900
TOP3=	10.2337	BOT3=	1.5000
TOP4=	1.2480	BOT4=	16.1639
TOP4=	1.2980	BOT4=	15.3920
TOP4=	1.4480	BOT4=	14.6201
TOP4=	1.6480	BOT4=	13.8482
TOP4=	1.8480	BOT4=	13.0763
TOP4=	2.0480	BOT4=	12.3044
TOP4=	2.2480	BOT4=	11.5324
TOP4=	2.4480	BOT4=	10.7605
TOP4=	2.6480	BOT4=	9.9886
TOP4=	2.8480	BOT4=	9.2167
TOP4=	3.0480	BOT4=	8.4448
TOP4=	3.2480	BOT4=	7.6729
TOP4=	3.4480	BOT4=	6.9010
TOP4=	3.6480	BOT4=	6.1290
TOP4=	3.8480	BOT4=	5.3571
TOP4=	4.0480	BOT4=	4.5852
TOP4=	4.2480	BOT4=	3.8133
TOP4=	4.4480	BOT4=	3.0414
TOP4=	4.6480	BOT4=	2.2695
TOP4=	4.8480	BOT4=	1.4975
TOP4=	5.0480	BOT4=	0.7256
TOP4=	5.2480	BOT4=	-0.0463
TOP4=	5.4480	BOT4=	-0.8182

```
CR HANDLING CHARGE    $   .35 / JOB          .35
11 LINES PRINTED PR1  $ 1.25 / K LN          .39
67 CARDS READ         $ 1.50 / K CD          .17
[illegible] PLOTTER VECTORS  $   .25 / 1[illegible]  .0[illegible]
22 MODEL 7[illegible] SECONDS  $25.00 / HOUR  .15
[illegible] MODEL 8[illegible] SECONDS  $12.50 / HOUR  .0[illegible]
                      TOTAL CHARGE $        .99

EIP 4[illegible] 14731  LOGGED OUT 05/26/74 19:42.  $   5.68 LEFT AFTER    28 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=100.*
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=15000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*.75)/(35.*35.)
            G=0.3956*S*S.(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=0.88
            BOT=1.
            A=560.*BM*(B*BOT+D*TOP)
            DEN=D*(2.*B*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
   60 FORMAT(' ',20X,'STH=',F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
   90 FORMAT(' ',20X,'SBH=',F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/6
            WRITE(5,110)SBCRIT
  110 FORMAT(' ',17X,'SBCRIT=',F10.3)
            P=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
   40 FORMAT(' ',18X,'DITOP=',F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
   50 FORMAT(' ',18X,'DIBOT=',F10.4)
            END
```

```
 (S) .U        0324(V) AL        032C(V) B         0334(V) DRA       033C(V) D
(V) POI        034C(V) E         0000(S) .B        0358(V) DST       0360(V) S
 (V) BM        037C(V) G         0388(V) TOP       0390(V) BOT       0394(V. A
-(V) DEN       0388(V) STH       0174(L) 60        0002(S) @I        03BC(V) C
```

```
  STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                    PAGE   2

. [V] SBH      01E2[L] 92        03C4[V] SBCRIT  0228[L] 110      03C8[V. P
-[V] DITOP    02A8[L] 42        .3D0[V] DIPOT   03-4[L] 50       0000[S] .V
-EL.          L
.


 GRAM LABELS:
-770 *MAIN*    2A64 .V        2894 .COMP     2A72 .I        2444 .R        295C .Z
-82A SA        2484 .A        2988 .MES      2936 .W        263F EXP       27C4 AI
 536 ALOG      28FC .RARG     2958 .5        263E AEXP      2960 .ERCNT    292E $8
 962 .0        2A26 .U        2B8E

-HY-POINTS:
 444 .-        2414 .A        2536 ALOG      263E AEXP      263E EXP       27C4 AI
 836 .         2894 .COMP     2A3A $6        28FC .RARG     292E $8        2958 .5
 95C .ZERO     2960 .ERCNT    2962 .0        2988 .MES      2A42 .U        2A68 .V
 A72 .I

-ON-BLOCKS:
 E


 EFINED SUBROUTINES:
 E


 NSFER ADDRESS 2070
-UTION REGIONS:

              STH= 18063.194
              SBH= 41334.957
           SBCRIT= 41021.625
            DITOP=   21.7217
            DIPOT=   49.7969
END


- VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74


CE HANDLING CHARGE    $   .35 / JOB          .35
 85 LINES PRINTED PR1 $ 1.25 / K LN          .11
 54 CARDS READ        $ 1.50 / K CD          .08
 77 PLOTTER VECTORS   $   .25 / 1770         .00
 16 MODEL 75 SECONDS  $25.00 / HOUR          .11
 07 MODEL 85 SECONDS  $12.50 / HOUR          .00
                      TOTAL CHARGE $         .65


EIR 49, 14731  LOGGED OUT 05/26/74 19:58.  $   2.78 LEFT AFTER    32 LOGINS.
```

SUMMARY

Length	= 1000'
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 30"
Material	- ALUMINUM
TOP	= 4.86"
BOT	= 1.00"
STH	= 18063.18
SBH	= 41334.96
SBCRIT	= 41021.80
DITOP	= 21.72'
DIBOT	= 49.71'

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5./5
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=60.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*D*A*AL*AL*.75)/(35.*35.)
            G=0.28386*S*S*(1.-POI*POI)/E
            A=9.*B*B*D/(140.*BM)
            C=3.*B*B*D/(70.*BM)
            F=3.*B*AL*D/(140.*BM)
      C     THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
            WRITE(5,17)
   17       FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT1=1.
   11       TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
            WRITE(5,22)TOP1,BOT1
   22       FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
            BOT1=BOT1+0.1
            IF(BOT1.GT.2.5)GO TO30
            GO TO 11
   30       TOP2=3.5
   31       BOT2=TOP2*(12.*B-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
            WRITE(5,40)TOP2,BOT2
   40       FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
            TOP2=TOP2+0.2
            IF(TOP2.GT.6. ) GO TO 50
            GO TO 31
   50       CONTINUE
      C     THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
            WRITE(5,60)
   60       FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
            BOT3=0.7
   61       TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
            WRITE(5,72)TOP3,BOT3
   72       FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
            BOT3=BOT3+0.05
            IF(BOT3.GT.1.5)GO TO 80
            GO TO 61
```

```
4B2          80 TOP4=1.
4BA          90 BOT4=(10.*(P+D)-(A+C)-DST*TOP4)/((C+F)*DST)
4CE             WRITE(5,95)TOP4,BOT4
4F2          95 FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4=',F9.4)
4FA             TOP4=TOP4+0.2
502             IF(TOP4.GT.5. )GO TO 100
50E             GO TO 81
518       100 CONTINUE
51C             END

 (S) .I         04CC(V) AL      04D8(V) B       04DA(V) DRA     04D8(V) D
 (V) PSI        04E8(V) E       04F0(S) .R      04F4(V) DST     04FC(V) S
 (V) SW         0518(V) G       0524(V) A       0530(V) C       053C(V) F
 (L) 10         054C(S) .I      0540(V) BOT1    0176(L) 11      0544(V) TOP1
 (L) 20         055C(L) 30      0558(V) TOP2    0234(L) 31      0560(V) BOT2
 (L) 40         056E(L) 50      0312(L) 60      0578(V) BOT3    0348(L) 61
 (V) TOP3       0588(L) 70      0414(L) 80      058C(V) TOP4    040A(L) 81
 (V) BOT4       05A2(L) 90      04BC(L) 100     00C0(S) .V
 (S) L
```

GRAY LABELS:

27W .MAIN	2C28 .W	2A58 .COMP	2C36 .I	2608 .R	2B20 .Z		
2A7E .A	2648 .A	2B7C .MES	29FA .W	2802 EXP	2988 AI		
29FA ALOG	2ACC .PARG	2B1C .S	2802 /EXP	2B24 .ERCNT	2AF2 $8		
2B24 .D	2BFA .L	3052					

TRY-POINTS:

26D2 .F	2648 .A	29FA ALOG	2802 AEXP	2802 EXP	2988 AI		
29FA .W	2A58 .COMP	2A7E $4	2ACC .PARG	2AF2 $8	2B1C .S		
2B20 .ZERO	2B24 .ERCNT	2B26 .D	2B7C .MES	2C06 .U	2C2C .V		
2C36 .I							

NON-BLOCKS:

E

DEFINED SUBROUTINES:

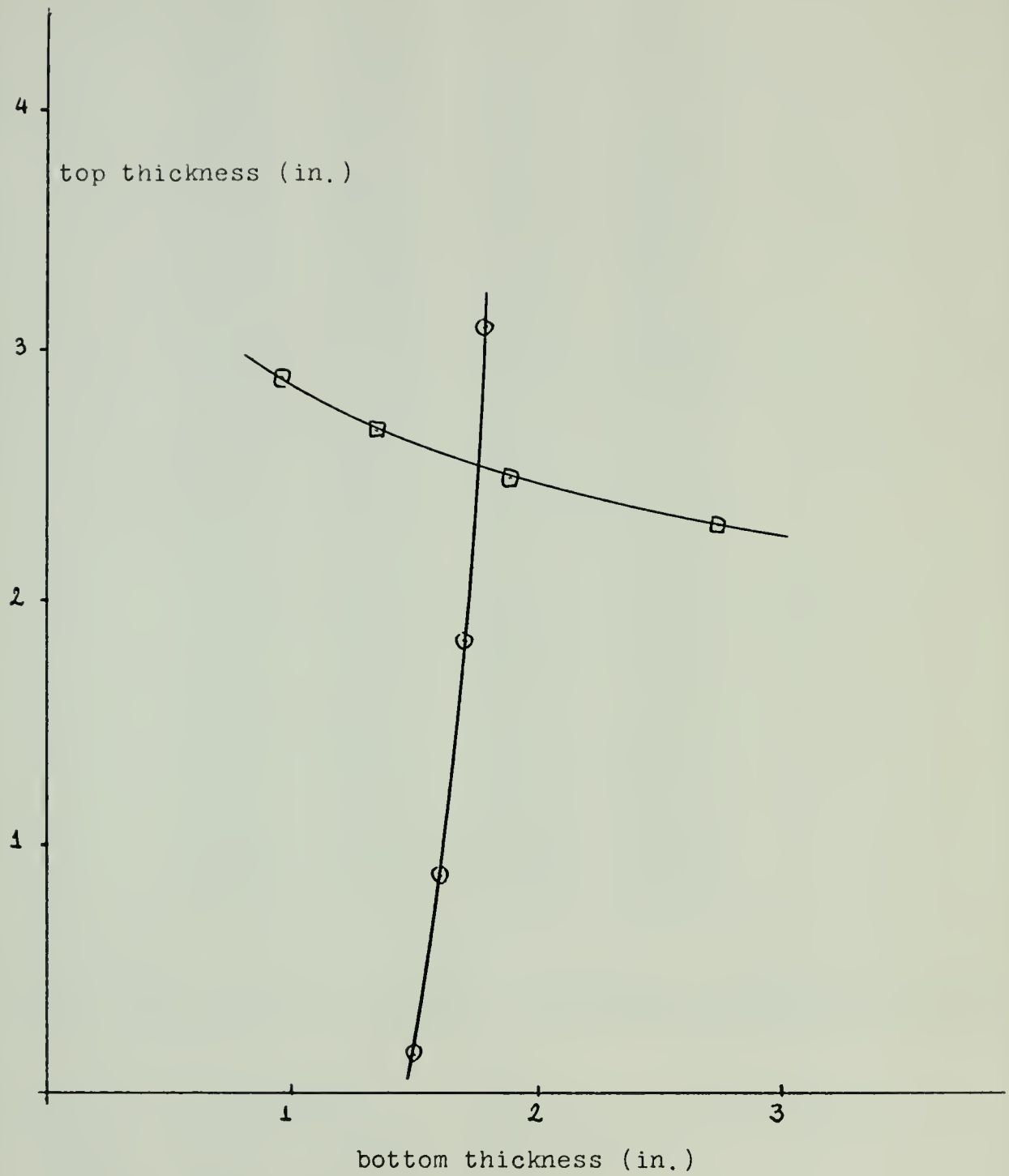
E

TRANSFER ADDRESS 27W

EXECUTION BEGINS:

TOP ASSUMED LARGER THAN BOTTOM

TOP1= 1.4642	BOT1= 1.0000
TOP1= 1.6725	BOT1= 1.1000
TOP1= 1.9149	BOT1= 1.2000
TOP1= 2.2029	BOT1= 1.3000
TOP1= 2.5491	BOT1= 1.4000
TOP1= 2.9747	BOT1= 1.5000
TOP1= 3.5061	BOT1= 1.6000
TOP1= 4.2112	BOT1= 1.7000
TOP1= 5.2019	BOT1= 1.8000
TOP1= 6.7147	BOT1= 1.9000
TOP1= 9.0645	BOT1= 2.0000
TOP1= 13.0952	BOT1= 2.1000
TOP1= 21.0105	BOT1= 2.2000
TOP1= 44.1143	BOT1= 2.3000
TOP1= 125.2764	BOT1= 2.4000
TOP1=-171.5708	BOT1= 2.5000
TOP2= 3.5000	BOT2= -11.8971
TOP2= 3.7 .0	BOT2= 91.0296
TOP2= 3.9 .0	BOT2= 8.7662
TOP2= 4.1 .0	BOT2= 4.3496
TOP2= 4.3 .0	BOT2= 2.7387
TOP2= 4. .0	BOT2= 1.5857
TOP2= 4.7 .0	BOT2= 1.3454
TOP2= 4.9 .0	BOT2= 0.9655
TOP2= 5.1 .0	BOT2= 0.6778
TOP2= 5.3 .0	BOT2= 0.4483
TOP2= 5.5 .0	BOT2= 0.2578
TOP2= 5.7 .0	BOT2= 0.0947
TOP2= 5.9 .0	BOT2= -0.0484


4
top thickness (in.)
3
2
1
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.2118      BOT3=   0.7000
TOP3=   0.2340      BOT3=   0.7500
TOP3=   0.6829      BOT3=   0.8000
TOP3=   1.1145      BOT3=   0.8500
TOP3=   1.2143      BOT3=   0.9000
TOP3=   1.2909      BOT3=   0.9500
TOP3=   1.3930      BOT3=   1.0000
TOP3=   1.4932      BOT3=   1.0500
TOP3=   1.6190      BOT3=   1.1000
TOP3=   1.7591      BOT3=   1.1500
TOP3=   1.8924      BOT3=   1.2000
TOP3=   1.9654      BOT3=   1.2500
TOP3=   2.2319      BOT3=   1.3000
TOP3=   2.4730      BOT3=   1.3500
TOP3=   2.6365      BOT3=   1.4000
TOP3=   2.8548      BOT3=   1.4500
TOP3=   2.9945      BOT3=   1.5000
TOP4=   1.0100      BOT4=  16.1639
TOP4=   1.2320      BOT4=  15.3920
TOP4=   1.4620      BOT4=  14.6201
TOP4=   1.6920      BOT4=  13.8482
TOP4=   1.9220      BOT4=  13.0763
TOP4=   2.1520      BOT4=  12.3044
TOP4=   2.3820      BOT4=  11.5324
TOP4=   2.6120      BOT4=  10.7605
TOP4=   2.8420      BOT4=   9.9886
TOP4=   3.0720      BOT4=   9.2167
TOP4=   3.3020      BOT4=   8.4448
TOP4=   3.5320      BOT4=   7.6729
TOP4=   3.7620      BOT4=   6.9010
TOP4=   3.9920      BOT4=   6.1290
TOP4=   4.2220      BOT4=   5.3571
TOP4=   4.4520      BOT4=   4.5852
TOP4=   4.6820      BOT4=   3.8133
TOP4=   4.9120      BOT4=   3.0414
TOP4=   5.1420      BOT4=   2.2695
TOP4=   5.3720      BOT4=   1.4975
TOP4=   5.6020      BOT4=   0.7256
END

END OF VIO OPERATING SYSTEM VERSION 1 REVISION   12 03/04/74 GENERATED  05/06/74  0

JOB HANDLING CHARGE    $   .35 / JOB          .35
164 LINES PRINTED PR1  $ 1.05 / K LN          .21
 67 CARDS READ         $ 1.50 / K CD          .10
 00 PLOTTER VECTORS    $   .25 / 100          .00
 19 MODEL 7  SECONDS   $25.00 / HOUR          .13
 00 MODEL 2  SECONDS   $12.50 / HOUR          .00
                 TOTAL CHARGE $               .79

LOGOFF 4:2 14731  LOGGED OUT 05/06/74 19:48.  $   4.89 LEFT AFTER    29 LOGINS.
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=12000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=60.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*2.75)/(35.*35.)
            G=0.3.396*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.52
            BOT=1.74
            A=560.*BM*(5*BOT+D*TOP)
            DEN=D*(2.*3*B*TOP*BOT+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP-TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,60)STH
         60 FORMAT(' ',20X,'STH='F10.3)
            C=560.*BM*(B*TOP+D*TOP)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
         90 FORMAT(' ',20X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/G
            WRITE(5,110)SBCRIT
        110 FORMAT(' ',17X,'SBCRIT='F10.3)
            P=2.*D-TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
            END
```

```
(3) .U      0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
0344[V] POI 034C[V] E       0000[S] .R      0358[V] DST     0360[V] S
0368[V] BM  037C[V] G       0388[V] TOP     0390[V] BOT     0398[V] A
03A0[V] DEN 03BC[V] STH     0174[L] 60      0000[S] .I      03C0[V] C
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
[V] STH      01E2[L] 90      03C8[V] SBCRIT  0228[L] 110     03CC[V] P
[V] DITOP    02A8[L] 40      03D4[V] DIBOT   0304[L] 50      0000[S] .V
END          L
F


PROGRAM LABELS:
2A7C .MAIN.   2A68 .V       2898 .COMP    2A76 @I       2448 .R       2960 .ZE
2B8E $6       2438 .A       29BC .MES     283A .W       2642 EXP      27C8 AIN
253A ALOG     2940 .PARG    295C .5       2642 AEXP     2964 .ERCNT   2932 $8
2964 .O       2A3A .U       3B92
2A76 AI


ENTRY-POINTS:
2448 .R       2438 .A       253A ALOG     2642 AEXP     2642 EXP      27C8 AIN
2808 .W       2808 .COMP    2B8E $6       2900 .PARG    2932 $8       295C .5
2A4C .ZERO    2964 .ERCNT   2964 .O       29BC .MES     2A46 .U       2A6C .V
2A76 AI


COMMON-BLOCKS:
NONE


DEFINED SUBROUTINES:
NONE


TRANSFER ADDRESS 2A7C
EXECUTION BEGINS:

               STH= 18034.023
               SBH= 31831.496
            SBCRIT= 31767.121
             DITOP=   25.8324
             DIBOT=   45.5962
END

F VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0


JOB HANDLING CHARGE    $  .35 / JOB          .35
 25 LINES PRINTED PR2  $ 1.25 / K LN         .11
 54 CARDS READ         $ 1.50 / K CD         .08
 00 PLOTTER VECTORS    $  .25 / 1000         .00
 14 MODEL 70 SECONDS   $25.00 / HOUR         .10
 00 MODEL 80 SECONDS   $12.50 / HOUR         .00
                     TOTAL CHARGE $          .64

PEIS 490 14731  LOGGED OUT 05/06/74 20:01.  $   2.14 LEFT AFTER    33 LOGINS.
```

SUMMARY

Length	= 1000'
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 60"
Material	- ALUMINUM
TOP	= 4.53"
BOT	= 1.76"
STH	= 18034.02
SBH	= 31831.49
SBCRIT	= 31767.27
DITOP	= 25.83'
DIBOT	= 45.60'

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNGS MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=120.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*DRA*AL*AL*0.75)/(35.*35.)
            C=0.3039*S*3.*(1.-POI*POI)/E
            A=9.*B**2*D/(140.*BM)
            C=3.*B*L*D/(70.*BM)
            F=3.*D*L*D/(140.*BM)
      C     THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
            WRITE(5,10)
         10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT1=2.
         11 TOP1=B*BOT1*BOT1*BOT1/((B+C)*G*DST-D*BOT1*BOT1)
            WRITE(5,20)TOP1,BOT1
         20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
            BOT1=BOT1+0.2
            IF(BOT1.GT.7. )GO TO30
            GO TO 11
         30 TOP2=3.5
         31 BOT2=TOP2*(12.*B-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
            WRITE(5,40)TOP2,BOT2
         40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
            TOP2=TOP2+0.2
            IF(TOP2.GT.6. ) GO TO 50
            GO TO 31
         50 CONTINUE
      C     THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
            WRITE(5,60)
         60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
            BOT3=1.
         61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
            WRITE(5,70)TOP3,BOT3
         70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
            BOT3=BOT3+0.2
            IF(BOT3.GT.3.5)GO TO 80
            GO TO 61
```

```
472       81  TOP4=1.
47A       81  BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
47E           WRITE(5,90)TOP4,BOT4
482       90  FORMAT(' ',25X,'TOP4=',F9.4,5X,'BOT4='F9.4)
49A           TOP4=TOP4+0.2
4A6           IF(TOP4.GT.4.5)GO TO 100
4B2           GO TO 81
4BC       100 CONTINUE
4BC           END
```

```
 (S) .U        04C0[V] AL       04C8[V] B        04D0[V] DRA      04D8[V] D
 (V) ROT       04E8[V] E        04F0[G] .R       04F4[V] DST      04FC[V] S
 (V) SM        0518[V] G        0524[V] A        0530[V] C        053C[V] F
 (L) 10        0800[S] AI       0540[V] BOT1     0176[L] 11       0548[V] TOP1
 (L) 21        0220[L] 30       055C[V] TOP2     0234[L] 31       0564[V] BOT2
 (L) 41        02FE[L] 50       0312[L] 60       0578[V] BOT3     0348[L] 61
 (V) TOP3      0338[L] 70       03C2[L] 80       0580[V] TOP4     040A[L] 81
 (V) BOT4      0472[L] 90       04BC[L] 100      0004[S] .V
 EG              L
```

```
PROGRAM LABELS:
0000 .MAIN.     2C1C .V          2A4C .COMP       2C2A AI          25FC .R          2B14 .Z
2A72 $6         263C .A          2B78 .MES        2BEE .W          27F6 EXP         297C AI
2EEE ALOG       2A84 .RARG       2B1A .E          27F6 AEXP        2B18 .ERCNT      2AE6 $8
2B18 .C         2BFE .L          3C46
```

```
ARRAY-POINTS:
2EFC .E         263C .A          2EEE ALOG        27F6 AEXP        27F6 EXP         297C AI
2EEE .W         2A4C .COMP       2A72 $6          2AB4 .RARG       2AE6 $8          2B10 .5
2B14 .ZERO      2B18 .ERCNT      2B1A .C          2B78 .MES        2BFA .U          2C20 .V
2C2A AI
```

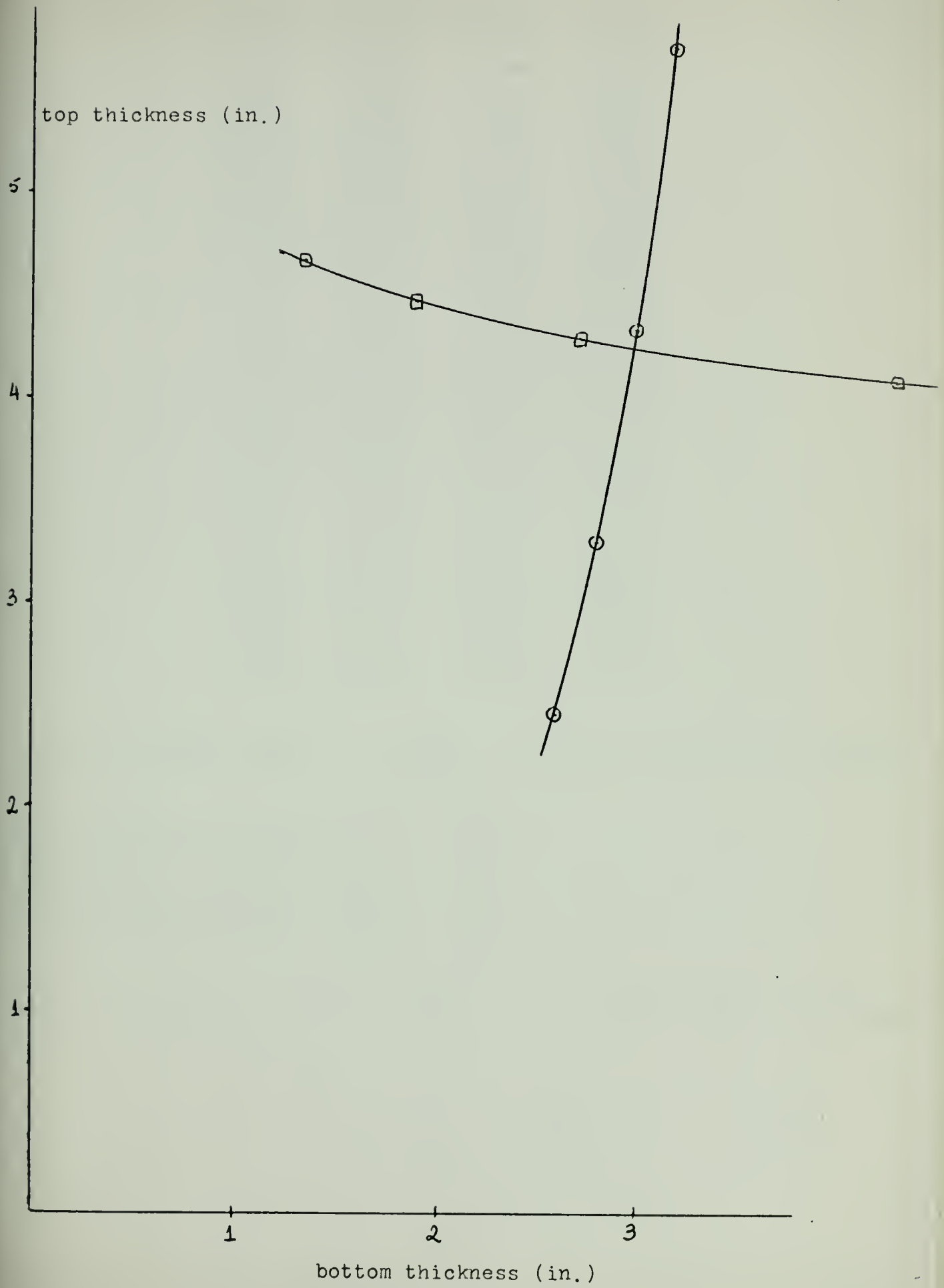
```
COMMON-BLOCKS:
E
```

```
DEFINED SUBROUTINES:
E
```

```
TRANSFER ADDRESS 2C70
EXECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1= 1.0684	BOT1= 2.0000
TOP1= 1.2451	BOT1= 2.2000
TOP1= 1.4398	BOT1= 2.4000
TOP1= 2.4668	BOT1= 2.6000
TOP1= 3.2242	BOT1= 2.8000
TOP1= 4.3404	BOT1= 3.0000
TOP1= 5.7503	BOT1= 3.2000
TOP1= 7.6285	BOT1= 3.4000
TOP1= 11.1159	BOT1= 3.6000
TOP1= 13.8165	BOT1= 3.8000
TOP1= 19.2132	BOT1= 4.0000
TOP1= 27.0646	BOT1= 4.2000
TOP1= 43.7752	BOT1= 4.4000
TOP1= 82.2119	BOT1= 4.6000
TOP1= 252.5668	BOT1= 4.8000
TOP1=-343.7314	BOT1= 5.0000
TOP1=-117.7282	BOT1= 5.2000
TOP1= -75.9276	BOT1= 5.4000
TOP1= -59.1147	BOT1= 5.6000
TOP1= -49.8704	BOT1= 5.8000
TOP1= -44.2485	BOT1= 6.0000
TOP1= -40.5128	BOT1= 6.2000
TOP1= -37.9004	BOT1= 6.4000
TOP1= -36.0977	BOT1= 6.6000
TOP1= -34.7715	BOT1= 6.8000
TOP1= -33.5580	BOT1= 7.0000
TOP2= 3.6360	BOT2= -11.8971
TOP2= 3.7260	BOT2= 91.0296
TOP2= 3.8160	BOT2= 2.7662
TOP2= 4.1160	BOT2= 4.3496
TOP2= 4.2060	BOT2= 2.7380
TOP2= 4.2960	BOT2= 1.8852
TOP2= 4.3860	BOT2= 1.3454
TOP2= 4.4760	BOT2= 0.9655
TOP2= 4.5660	BOT2= 0.6778
TOP2= 4.6560	BOT2= 0.4483
TOP2= 4.7460	BOT2= 0.2578
TOP2= 4.8360	BOT2= 0.0947
TOP2= 4.9260	BOT2= -0.0484


top thickness (in.)
5
4
3
2
1
1
2
3
bottom thickness (in.)

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -.2[illegible]    BOT3=   1.0000
TOP3=  -.1[illegible]    BOT3=   1.2000
TOP3=  -.0[illegible]    BOT3=   1.4000
TOP3=   .1[illegible]    BOT3=   1.6000
TOP3=   .4[illegible]    BOT3=   1.8000
TOP3=   .7[illegible]    BOT3=   2.0000
TOP3=  1.2[illegible]    BOT3=   2.2000
TOP3=  1.7[illegible]    BOT3=   2.4000
TOP3=  2.4[illegible]    BOT3=   2.6000
TOP3=  3.2[illegible]    BOT3=   2.8000
TOP3=  4.1[illegible]    BOT3=   3.0000
TOP3=  5.2[illegible]    BOT3=   3.2000
TOP3=  6.[illegible]     BOT3=   3.4000
TOP4=  1.[illegible]     BOT4=  16.1639
TOP4=  1.[illegible]     BOT4=  15.3920
TOP4=  1.[illegible]     BOT4=  14.6201
TOP4=  1.[illegible]     BOT4=  13.8482
TOP4=  1.[illegible]     BOT4=  13.0763
TOP4=  2.[illegible]     BOT4=  12.3044
TOP4=  2.[illegible]     BOT4=  11.5324
TOP4=  2.[illegible]     BOT4=  10.7605
TOP4=  2.[illegible]     BOT4=   9.9886
TOP4=  2.[illegible]     BOT4=   9.2167
TOP4=  3.[illegible]     BOT4=   8.4448
TOP4=  3.[illegible]     BOT4=   7.6729
TOP4=  3.[illegible]     BOT4=   6.9010
TOP4=  3.[illegible]     BOT4=   6.1290
TOP4=  3.[illegible]     BOT4=   5.3571
TOP4=  4.[illegible]     BOT4=   4.5852
TOP4=  4.[illegible]     BOT4=   3.8133
TOP4=  4.[illegible]     BOT4=   3.0414
END

F VIO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED 05/06/74

OF HANDLING CHARGE      $   .35 / JOB          .35
'67 LINES PRINTED PR1   $ 1.25 / K LN          .21
67 CARDS READ           $ 1.50 / K CD          .10
00 PLOTTER VECTORS      $   .25 / 1000         .00
20 MODEL 70 SECONDS     $25.00 / HOUR          .14
07 MODEL 50 SECONDS     $12.50 / HOUR          .00
                         TOTAL CHARGE $        .80

EIP 404 14731  LOGGED OUT 05/06/74 19:52.  $    4.09 LEFT AFTER    30 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=1[illegible]
            B=AL/5.76
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNGS MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*12.**6
      C     *DST* IS THE DESIGN STRESS
            DST=1[illegible].
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=12.
      C     *DT* IS THE DEADWEIGHT
            DT=(6.*DRA*AL*AL*.75)/(35.*35.)
            C=.313596*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=4.27
            BOT=2.98
            A=58[illegible]*(B*(TOP+BOT))
            DEN=D*(5.*B*(TOP+BOT)+2.*B*D*TOP*(TOP+BOT)+(D*D*TOP*TOP))
      C     *STH* IS THE STRESS ON TOP DUE TO SAGGING
            STH=A/DEN
            WRITE(5,60)STH
   60       FORMAT(' ',25X,'STH='F10.3)
            C=56[illegible]*(B*TOP+D.T[illegible])
      C     *SBH* IS THE STRESS ON BOT DUE TO SAGGING
            SBH=C/DEN
            WRITE(5,90)SBH
   90       FORMAT(' ',25X,'SBH='F10.3)
      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
            SBCRIT=BOT*BOT/B
            WRITE(5,110)SBCRIT
  110       FORMAT(' ',17X,'SBCRIT='F10.3)
            B=2.*D*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*TOP)/B
            WRITE(5,40)DITOP
   40       FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*TOP)/B
            WRITE(5,50)DIBOT
   50       FORMAT(' ',18X,'DIBOT='F10.4)
            END
```

```
[S] .ID     0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
[V] POI     034C[V] E       0350[S] .R      0358[V] DST     036[illegible][V] S
[V] DT      037C[V] G       0388[V] TOP     0390[V] BOT     0398[V] A
[V] DEN     03AC[V] STH     0174[I] 60      0002[S] @I      03C0[V] C
```

```
(V) SBR      0312[L] 90        3C0[V] SBCRIT  0228[L] 110      03CC[V] P
(V) TITOP    0218[L] 4V        3D4[V] DIPOT   0304[L] 5W       0000[S] .V
```

```
PROGRAM LABELS:
.70 INITIA   2443 .V      2498 .COMP    2476 .I      2448 .R      2960 .Z
.E 24        2488 .J      29BC .YES     2A3A .W      2642 EXP     27C8 AI
.3A ALOG     2A2A .ARG    2950 .5       2642 .EXP    2964 .ERCNT  2912 .8
24 .0        243A .L      3W92
```

```
ENTRY POINTS:
44C .F       2485 .J      2A32 .LOG     2642 EXP     2642 EXP     27C8 AI
2CA .        2A9A .COPY   2A3E .A      2946 .RARG   2932 .3      295C .5
2A4 .SQRT    2964 .ERCNT  2A6A .0       295C .YES    2446 .U      2A0C .V
246 .Y
```

```
EXTERNAL REFERENCES:
E
```

```
DEFINED SUBROUTINES:
E
```

```
TRANSFER ADDRESS 2276
EXECUTION BEGINS:

              SIN= 1795e.723
              SQR= 2285e.766
           SRCRIT= 2276e.[illegible]8
            TITOP=   31.4316
            TIBOT=   39.9[illegible]7
END
```

```
F4IO OPERATING SYSTEM VERSION 1 REVISION 012 03/04/74 GENERATED  5/06/74
```

```
CE HANDLING CHARGE    $  .25 / JOB          .35
55 LINES PRINTED PR1  $ 1.25 / 1 L          .11
54 CARDS READ         $ 1.50 / 1 C          .08
0% PLOTTER VECTORS    $  .25 / 100          .00
15 MODEL 71 SECONDS   $25.71 / HOUR         .11
42 MODEL 51 SECONDS   $12.60 / HOUR         .07
                   TOTAL CHARGE $           .65
```

```
TIME 49' 14731  LOGGED OUT 05/06/74 20:03.  $   1.49 LEFT AFTER    34 LOGINS.
```

SUMMARY

Length	= 1000'
Beam	= AL/5.75
Draft	= B/3.3
Depth	= AL/14
DST	= 18000 psi
S	= 120"
Material	- ALUMINUM
TOP	= 4.27"
BOT	= 2.98"
STH	= 17958.79
SBH	= 22852.76
SBCRIT	= 22768.12
DITOP	= 31.43'
DIBOT	= 39.99' or 40.00'

Looking at the following table we can also observe for the aluminum the effect of changing S on the neutral axis location and the compressive stresses resulting on thebottom plating.

CASE	S inches	TOP inches	BOT inches	SBH psi	SBCRIT psi	DITOP ft	DIBOT ft
1	10	5.35	0.363	53000	49000 *	18.09	53.34
2	30	4.86	1.00	41000	41000	21.72	49.71
3	60	4.53	1.76	32000	32000	25.83	45.60
4	120	4.27	2.98	23000	23000	31.43	40.00

(*) This difference may result from inaccuracy in reading the plot.

Here again the values of TOP and BOT may allow for a quick evaluation of the weight relationship between the four cases.

One run was also made in the case of the aluminum for AL=500 ft and the results are here included.

```
      C     *AL* IS THE LENGHT
            AL=500.
            B=AL/2.
      C     *DRA* IS THE DRAFT
            DRA=B/3.
            D=AL/9.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=1.0*10**6
      C     *DST* IS THE DESIGN STRESS
            DST=18000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(D*DRA*AL*AL*0.75)/(35.*35.)
            G=.0336*S*S*(1.-POI*POI)/E
            A=9.0*D/(14.0*BM)
            C=3.0*D/(7.0*BM)
            F=3.0*D/(14.0*BM)
      C     THICKNESS OF TOP ASSUMED LARGER THAN BOTTOM THICKNESS
            WRITE(6,10)
         10 FORMAT('1',25X,'TOP ASSUMED LARGER THAN BOTTOM')
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT1=0.1
         11 TOP1=B*BOT1*BOT1*BOT1/((B+D)*G*DST-D*BOT1*BOT1)
            WRITE(6,20)TOP1,BOT1
         20 FORMAT(' ',25X,'TOP1=',F9.4,5X,'BOT1='F9.4)
            BOT1=BOT1+0.25
            IF(BOT1.GT.1.)GO TO 30
            GO TO 11
         30 TOP2=0.1
         31 BOT2=TOP2*(12.*B-(C+F)*DST*TOP2)/(DST*(A+C)*TOP2-12.*B)
            WRITE(6,40)TOP2,BOT2
         40 FORMAT(' ',25X,'TOP2=',F9.4,5X,'BOT2='F9.4)
            TOP2=TOP2+0.25
            IF(TOP2.GT.1.)GO TO 50
            GO TO 31
         50 CONTINUE
      C     THICKNESS OF BOTTOM ASSUMED LARGER THAN TOP
            WRITE(6,60)
         60 FORMAT('1',25X,'BOTTOM ASSUMED LARGER THAN TOP')
            BOT3=0.1
         61 TOP3=((B+D)*BOT3*BOT3*BOT3-D*G*DST*BOT3)/(B*G*DST)
            WRITE(6,70)TOP3,BOT3
         70 FORMAT(' ',25X,'TOP3=',F9.4,5X,'BOT3='F9.4)
            BOT3=BOT3+0.25
            IF(BOT3.GT.1.)GO TO 80
            GO TO 61
```

```
-02          90 TOP4=A.1
-01          91 BOT4=(12.*(B+D)-(A+C)*DST*TOP4)/((C+F)*DST)
-45             WRITE(5,92)TOP4,BOT4
-12          92 FORMAT(' ',20X,'TOP4=',F9.4,5X,'BOT4='F9.4)
-91             TOP4=TOP4+(.05
-A0             IF(TOP4.GT.1.)GO TO 100
-H-             GO TO 91
-0C          100 CONTINUE
-6C             END
```

[C] .U	.40C[V] AL	4C8[V] B	04D0[V] DRA	04D8[V] D			
[C] PCI	.44B[V] E	4F8[C] .R	0434[V] DST	04FC[V] S			
[C] .W	.518[V] C	524[V] A	052C[V] C	0534[V] F			
[L] .C	.W0C[S] .I	538[V] BOT1	0176[L] 11	054M[V] TOP1			
[L] 2.	2EC[L] 30	55C[V] TOP2	0234[L] 31	0554[V] BOT2			
[L] 4.	2F8[L] 50	318[L] 60	.5A4[V] BOT3	0348[L 61			
[C] TOP3	.30A[L] 70	.4 8[L] 80	05AC[V] TOP4	040A[L] 81			
[C] .BT4	478[L] 90	4A8[L] 100	0B[A[S] .V				

```
0.
```

```
BEAM LABELS:
```

270 .XXI.	2C14 .\	2A34 .COMP	2C12 I	25E4 .R	2AFC .Z		
2AA 24	2624 ..	2B5D .MES	2906 .1	27DF EXP	2964 AI		
6A6 ALOG	2A5C .PARG	2AF2 .S	27DF AEXP	2B0(.ERCNT	2ACE $8		
2B7 .D	2C14 .\	2D2F					

```
NON-FORMATS:
```

2F4 .E	2624 .1	2606 ALOG	27DE AEXP	27DE EXP	2964 AI		
2F6 .\	2A34 .COMP	2A5A 24	2A9C .PARG	2ACE $8	2AF8 .5		
ABC .ZERO	2B5C .ERCNT	2B32 .D	2B58 .MES	2BE2 .U	2C28 .V		
C12 .I							

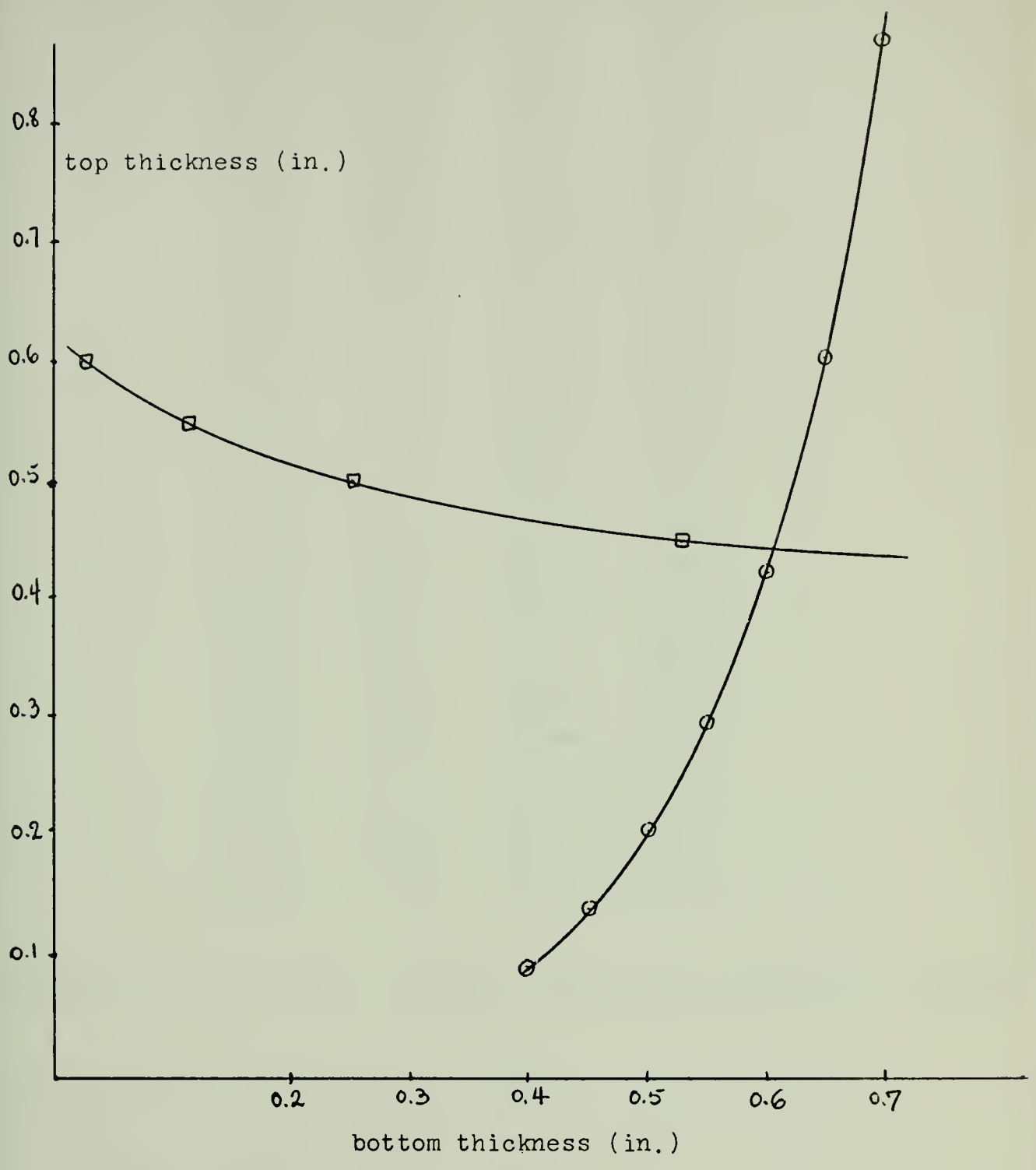
```
NON-BLOCKS:
E


DEFINED SUBROUTINES:
E


TRANSFER ADDRESS 2070
EXECUTION BEGINS:
```

TOP ASSUMED LARGER THAN BOTTOM

TOP1= [illegible]	BOT1= 0.1000
TOP1= [illegible]	BOT1= 0.1500
TOP1= [illegible]	BOT1= 0.2000
TOP1= [illegible]	BOT1= 0.2500
TOP1= [illegible]	BOT1= 0.3000
TOP1= [illegible]	BOT1= 0.3500
TOP1= [illegible]	BOT1= 0.4000
TOP1= [illegible]	BOT1= 0.4500
TOP1= [illegible]	BOT1= 0.5000
TOP1= [illegible]	BOT1= 0.5500
TOP1= [illegible]	BOT1= 0.6000
TOP1= [illegible]	BOT1= 0.6500
TOP1= [illegible]	BOT1= 0.7000
TOP1= [illegible]	BOT1= 0.7500
TOP1= [illegible]	BOT1= 0.8000
TOP1= [illegible]	BOT1= 0.8500
TOP1= [illegible]	BOT1= 0.9000
TOP1= [illegible]	BOT1= 0.9500
TOP1= -16.65[illegible]1	BOT1= 1.0000
TOP2= [illegible]	BOT2= -0.1017
TOP2= [illegible]	BOT2= -0.1687
TOP2= [illegible]	BOT2= -0.2587
TOP2= [illegible]	BOT2= -0.3997
TOP2= [illegible]	BOT2= -0.6955
TOP2= [illegible]	BOT2= -2.1234
TOP2= [illegible]	BOT2= 1.7868
TOP2= [illegible]	BOT2= 0.5333
TOP2= [illegible]	BOT2= 0.2515
TOP2= [illegible]	BOT2= 0.1143
TOP2= [illegible]	BOT2= 0.0258
TOP2= [illegible]	BOT2= -0.0403
TOP2= [illegible]	BOT2= -0.0944
TOP2= [illegible]	BOT2= -0.1413
TOP2= [illegible]	BOT2= -0.1835
TOP2= [illegible]	BOT2= -0.2224
TOP2= [illegible]	BOT2= -0.2591
TOP2= [illegible]	BOT2= -0.2941
TOP2= [illegible]	BOT2= -0.3277



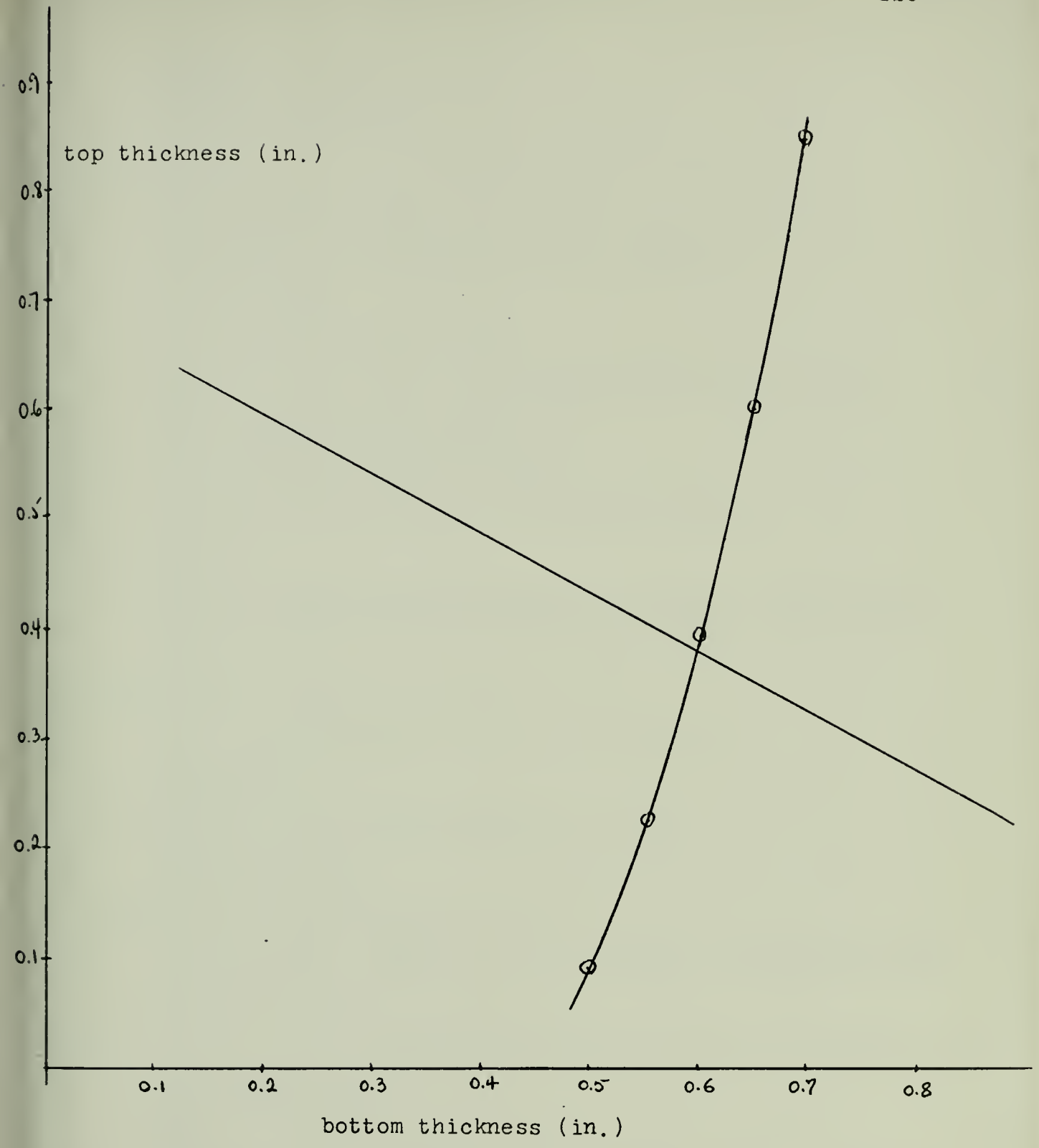
Intersection not accepted; assumed Top > Bot ended up with Bot > Top.

```
BOTTOM ASSUMED LARGER THAN TOP
TOP3=  -0.0[illegible]     BOT3=   0.1000
TOP3=  -0.1[illegible]     BOT3=   0.1500
TOP3=  -0.1[illegible]     BOT3=   0.2000
TOP3=  -0.1[illegible]     BOT3=   0.2500
TOP3=  -0.1[illegible]     BOT3=   0.3000
TOP3=  -0.1[illegible]     BOT3=   0.3500
TOP3=  -0.0[illegible]     BOT3=   0.4000
TOP3=  -0.0[illegible]     BOT3=   0.4500
TOP3=   0.0[illegible]     BOT3=   0.5000
TOP3=   0.2[illegible]     BOT3=   0.5500
TOP3=   0.3[illegible]     BOT3=   0.6000
TOP3=   0.4[illegible]     BOT3=   0.6500
TOP3=   0.5[illegible]     BOT3=   0.7000
TOP3=   1.1[illegible]     BOT3=   0.7500
TOP3=   1.4[illegible]     BOT3=   0.8000
TOP3=   1.8[illegible]     BOT3=   0.8500
TOP3=   2.3[illegible]     BOT3=   0.9000
TOP3=   2.9[illegible]     BOT3=   0.9500
TOP3=   3.4[illegible]     BOT3=   1.0000
TOP4=   0.1[illegible]     BOT4=   1.1275
TOP4=   0.1[illegible]     BOT4=   1.0344
TOP4=   0.2[illegible]     BOT4=   0.9414
TOP4=   0.2[illegible]     BOT4=   0.8484
TOP4=   0.3[illegible]     BOT4=   0.7554
TOP4=   0.3[illegible]     BOT4=   0.6623
TOP4=   0.4[illegible]     BOT4=   0.5693
TOP4=   0.4[illegible]     BOT4=   0.4763
TOP4=   0.5[illegible]     BOT4=   0.3832
TOP4=   0.5[illegible]     BOT4=   0.2902
TOP4=   0.6[illegible]     BOT4=   0.1972
TOP4=   0.6[illegible]     BOT4=   0.1042
TOP4=   0.7[illegible]     BOT4=   0.0111
TOP4=   0.7[illegible]     BOT4=  -0.0819
TOP4=   0.8[illegible]     BOT4=  -0.1749
TOP4=   0.8[illegible]     BOT4=  -0.2680
TOP4=   0.9[illegible]     BOT4=  -0.3610
TOP4=   0.9[illegible]     BOT4=  -0.4540
TOP4=   1.0[illegible]     BOT4=  -0.5470
END

F VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74


JOB HANDLING CHARGE    $   .35 / JOB          .35
173 LINES PRINTED PR1  $ 1.25 / K LN          .22
 67 CARDS READ         $ 1.50 / K CD          .1
   PLOTTER VECTORS     $   .25 / 10K          .07
   MODEL 75 SECONDS    $25.00 / HOUR          .14
   MODEL 85 SECONDS    $12.50 / HOUR          .00
                       TOTAL CHARGE $         .81


EIR 4GM 14731  LOGGED OUT 05/06/74 20:09.  $     .68 LEFT AFTER     35 LOGINS.
```



this intersection is acceptable Bot > Top

```
      C     *AL* IS THE LENGHT
            AL=500.
            B=AL/8.
      C     *DRA* IS THE DRAFT
            DRA=B/3.
            D=AL/9.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=0.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=12000.
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=30.
      C     *BM* IS THE BENDING MOMENT
            BM=(B*D*DRA*AL*AL*0.75)/(35.*35.)
            G=0.3937*S*S*(1.-POI*POI)/E
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=0.3
            BOT=0.5
            A=562.*BM*(B*BOT+D)*BOT)
            DEN=(3.*B*B*TOP*BOT+2.*B*D*BOT*(TOP+BOT)+(D*D*BOT*BOT))
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
            STH=A/DEN
            WRITE(5,40)STH
   40 FORMAT(' ',20X,'STH=',F10.3)
            C=562.*BM*(B*TOP+D*BOT)
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
            SBH=C/DEN
            WRITE(5,90)SBH
   90 FORMAT(' ',20X,'SBH=',F10.3)
      C     *SECRIT* IS THE CRITICAL STRESS ON BOT
            SECRIT=FOT*BOT/G
            WRITE(5,110)SECRIT
  110 FORMAT(' ',17X,'SBCRIT=',F10.3)
            P=2.*D*BOT+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*BOT)/P
            WRITE(5,40)DITOP
   40 FORMAT(' ',18X,'DITOP=',F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*BOT)/P
            WRITE(5,50)DIBOT
   50 FORMAT(' ',18X,'DIBOT=',F10.4)
            END
```

```
[S] ..  0324[V] AL      032C[V] B       0334[V] DRA     033C[V] D
[V] POI 0340[V] E       0000[S] .R      0358[V] DST     0360[V] S
[V] BM  0370[V] G       0388[V] TOP     0390[V] BOT     0398[V] A
[V] DEN 03B8[V] STH     0174[L] 60      0003[S] @I      03BC[V] C
```

```
[V] SBH      01F2[L] 90      03C4[V] SBCRIT  0228[L] 110     03C8[V] P
[V] DITOP    02A8[L] 40      03D0[V] DIPOT   03D4[L] 50      0000[S] .V
EC          L.
```

```
GRAM LABELS:
*70 *MAIN*   2A64 .V        2894 .COMP      2A72 .I         2444 .R         295C .ZE
80A $6       2424 .A        2982 .MES       2936 .W         263E EXP        27C4 AII
836 ALOG     29EC .PARG     2958 .B         263E AEXP       2960 .ERCNT     292E $8
9AC .D       2A36 .L        3A8E
```

```
ENTRY POINTS:
444 .B       2454 .B        2536 ALOG       263E AEXP       263E EXP        27C4 AII
836 .        2894 .COMP     2A2A $6         29EC .PARG      292E $8         2958 .B
9AC .7EF     2960 .ERCNT    2962 .D         2938 .MES       2A42 .U         2A68 .V
A72 .T
```

```
UNDEFINED:
E
```

```
DEFINED SUBROUTINES:
E
```

```
USER ADDRESS 2970
OPTION REGIONS:

          STH= 18080.464
          SBH= 14570.037
       SBCRIT= 14767.777
        DITOP=    34.737
        DIPOT=    24.719
NP
```

```
VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/06/74  0


OE HANDLING CHARGE    $   .05 / JOB          .35
85 LINES PRINTED PR1  $ 1.05 / K LN          .11
54 CARDS READ         $ 1.50 / K CD          .08
00 PLOTTER VECTORS    $   .05 / 1000         .00
16 MODEL 75 SECONDS   $25.00 / HOUR          .11
00 MODEL 91 SECONDS   $12.50 / HOUR          .00
                   TOTAL CHARGE $            .65


EIP 451 14731  LOGGED OUT 05/06/74 20:13.  $     .03 LEFT AFTER     36 LOGINS.
```

SUMMARY

Length	= 500'
Beam	= AL/8
Draft	= B/3
Depth	= AL/9
DST	= 18000 psi
S	= 30"
Material	- ALUMINUM
TOP	= 0.38"
BOT	= 0.6"
STH	= 18089.66
SBH	= 14578.14
SBCRIT	= 14767.85
DITOP	= 30.76"
DIBOT	= 24.79"

HOGGING BENDING MOMENT=SAGGING BENDING MOMENT

DESIGN STRESS IN TENSION=DESIGN STRESS IN COMPRESSION

From the preceding section we can understand the need to put some limit on the value of the compressive stresses, and perhaps also the inefficiency of considering the value of S (the spacing between longitudinal stiffening members) as an input to the problem.

In this section we will consider a bending moment of the same magnitude in both hogging and in sagging and the stress in either tension or compression will have as upper limit the design stress.

Since the bending moment is the same, it is intuitive that the thickness required to resist tension on top and compression on bottom (buckling) when the hogging moment is acting will also be respectively the thicknesses to resist tension on bottom and buckling on top when we consider the sagging moment. We would end up then with a thickness on top required by the hogging moment TOPH, a thickness on bottom required by the hogging moment, as well as a thickness on top required by the sagging moment TOPS and a thickness on bottom required by the sagging moment BOTS.

Since HM = SM we must obtain

TOPS = BOTH = t1 and BOTS = TOPH = t2

and we will end up considering the largest t1 or t2, to be the thickness of the top and bottom simultaneously.

Assume for instance that t1 > t2 then if we decide on t1for

thickness of the top as well as at the bottom, we will verify that we have overdesigned because TOPS = t1 corresponds to BOTS = t2 which plugged into the expression for I gives a smaller value than using TOPS = t1 with BOTH = t1 that will give a larger value for I; this larger I value when used in

$$STR = \frac{BM*Y}{I}$$

will give a smaller STR value than the design stress and we could use a smaller thickness, may be between t1 and t2 for both the top and bottom and satisfy the DST requirement.

This means that we must incorporate in this analysis the fact already known that when BM (hogging) is equal to BM (sagging) we will have to consider the neutral axis half way between top and bottom which means that the thickness of the top shall be equal to the thickness of the bottom for a geometrically symmetrical cross section.

Let's determine the formulas that will best serve this case then:

HM = SM = BM

DITOP = DIBOT = D*(B*t+D*t)/(2*D*t+B*(2*t))

t = TOP = BOT = TS

$$I = 2*D*D*t*\frac{3*B*B+D*D+4*B*D}{D+B}$$

Now we can write $$STR = \frac{BM*DITOP}{I} = \frac{BM*DIBOT}{I} = DST$$

and the instability formula

$$t = S * \sqrt{0.30396 * \frac{1-POI*POI}{E} * DST}$$

Where S is the spacing between longitudinals.

We see thus that we cannot have more than two equations and so we must seek for two variables. A quick inspection and one can see that knowing BM, B, D, the material properties and the design stress DST we have left to determine what should be the thickness of the plating (t) and the corresponding frame spacing (S). Solving the equations with this in mind, we obtain

$$BM = 1.37143*B*T*AL*AL \quad lb*ft$$

and from $STR = \frac{BM*Y}{I}$ we obtain

$$DST = \frac{BM*(D+B)}{4*D*t(3*B*B+D*D+4*B*D)}$$

which gives

$$t = \frac{BM*(D+B)}{4*D*DST*(3*B*B+D*D+4*B*D)}$$

and also

$$S = \frac{t}{\sqrt{\frac{0.30396*(1-POI*POI)*DST}{E}}}$$

These formulas will give for a prescribed set of dimensions (ft) and a particular material subject to bending BM (lb*ft) the thickness t (inches) and the spacing of longitudinal stiffening members S (inches) required.

HOGGING MOMENT AND SAGGING MOMENT OF DIFFERENT MAGNITUDES THE DESIGN STRESS IS THE SAME IN TENSION AND IN COMPRESSION

Let's consider now the case where the magnitude of HM is different than the value for SM.

We have in this case:

$$DITOP = \frac{D*(B*BOT+D*TS)}{2*D*TS+B*(TOP+BOT)}$$

$$DIBOT = \frac{D*(B*TOP=D*TS)}{\text{SAME DENOMINATOR}}$$

$$I = 4*D*D*\frac{3*B*B*TOP*BOT+(D*TS)^2+2*B*D*TS*(TOP+BOT)}{\text{SAME DENOMINATOR}}$$

$$STH = \frac{HM*DITOP}{I} \qquad STS = \frac{SM*DITOP}{I}$$

$$SBH = \frac{HM*DIBOT}{I} \qquad SBS = \frac{SM*DIBOT}{I}$$

$$BOT = \sqrt{G}\ \sqrt{SBH} \qquad TOP = \sqrt{G}\ \sqrt{STS}$$

where $$G = 0.30396*\frac{S^2*(1-POI*POI)}{E}$$

Looking at these equations, we know that the result obtained for the thicknesses is going to determine the value of DITOP, DIBOT and I. If furthermore we restrain the stresses from being larger than DST we will undoubtedly want them to end up being DST otherwise if they are smaller we are not using the material efficiently.

We thus have

DST = STH = HM*K1 DST = STS = SM*K1 where K1 = DITOP/I

DST = SBH = HM*K2 DST = SBS = SM*K2 where K2 = DIBOT/I

This tells us that if for instance HM > SM

we should be considering DST = STH = HM*K1

and DST = SBH = HM*K2

because the other two equations will determine lower stresses and are thus within the requirement of not exceeding the design stress, being automatically satisfied.

Now from these equations we can see that if the design stress required for the top, (in tension for the case of HM > SM; note that for the case SM > HM the other two equations should be considered and the conclusions are similar), is going to be the same one as required for the bottom (in compression), we must have K1 = K2 and so DITOP = DIBOT and the neutral axis will again end up being located halfway between top and bottom for a geometrically symmetrical cross section.

We can here use the same two equations derived in the previous section to determine (t) and (S). The moment to be considered here will be the larger of HM or SM instead of BM.

HOGGING MOMENT LARGER THAN SAGGING MOMENT
DESIGN STRESS IN COMPRESSION LARGER THAN DESIGN STRESS IN TENSION

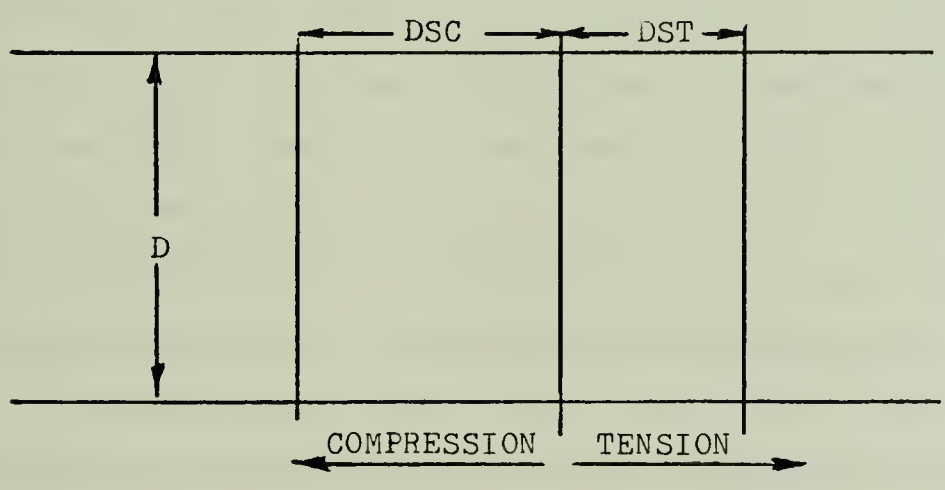
Thesituation we are analysing in this section

$$HM > SM$$

$$DSC > DST$$

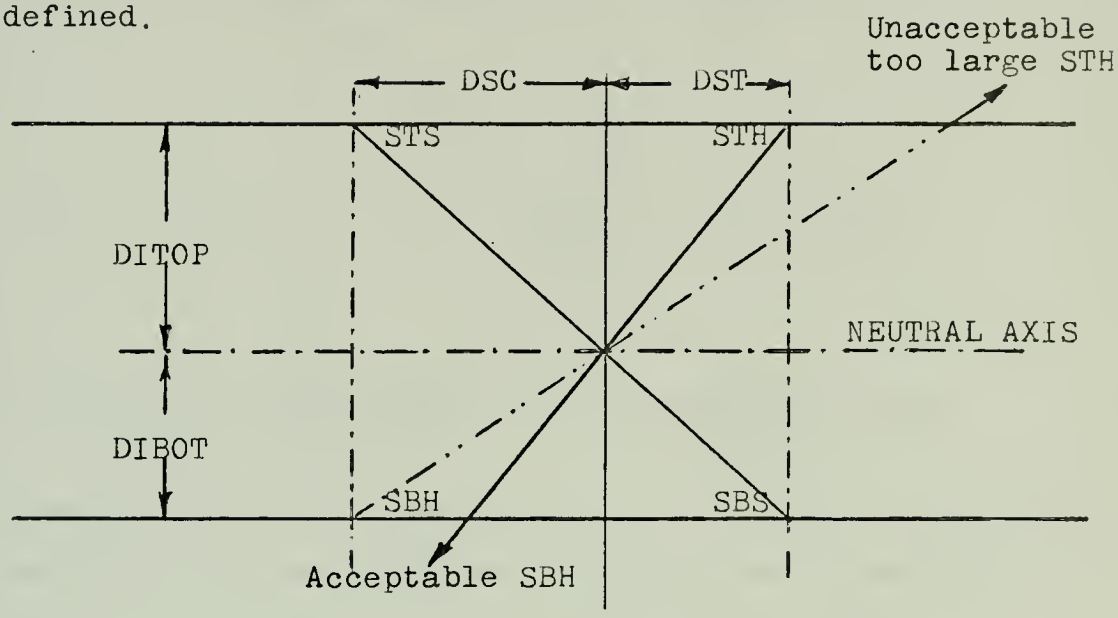
is perhaps more interesting than the previous ones because its study provided us with a much simpler method for determining the thicknesses and the neutral axis location; we call here the attention of the reader to fully understand the steps of this section because the following sections till the end of this work will use this same method of analysis applied totheir own particular case.

Indicated in the next diagram are the ranges within which we may stress the material in order to satisfy the requirement of not exceeding DSC or DST.



Let's consider now that we will try to determine the best position for the neutral axis by first gaining some insight into

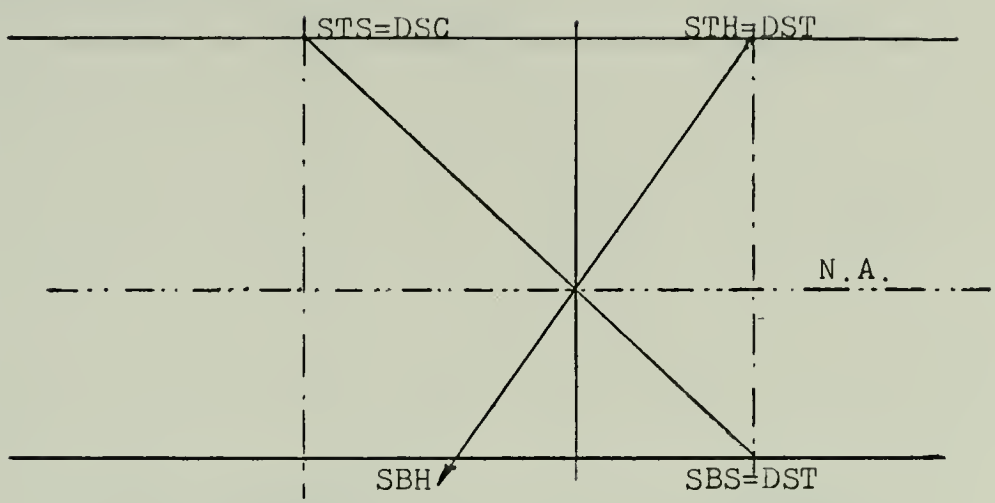
the geometry of the stress distributions and the stress limits already defined.



From the previous diagram we may easily understand that if we decide to stress the material to its maximum in tension and compression when under the effect of a sagging bending moment (SBS - STS) we end up with a neutral axis closer to the bottom due to the fact that DST < DSC and we see that when considering the hogging moment the only possible alternative left is to limit the stress caused by this moment in tension on top STH=DST; in this case the compressive stress on the bottom SBH would automatically fall inside the acceptable range.

If for the hogging moment we choose to allow the stress in compression on the bottom to attain its maximum value SBH=DSC we see from the diagram that we are forcing the STH to fall outside of the acceptable range. We are left in this situation with an acceptable solution so far and we must investigate it further.

At this stage we have



We may see from the diagram that we are asking for SBS=STH= =DST to have the same value and at the same time to have the neutral axis located closer to the bottom DITOP > DIBOT.

We note that the equations that give STH and SBS are

STH = HM*DITOP/I

and SBS = SM*DIBOT/I

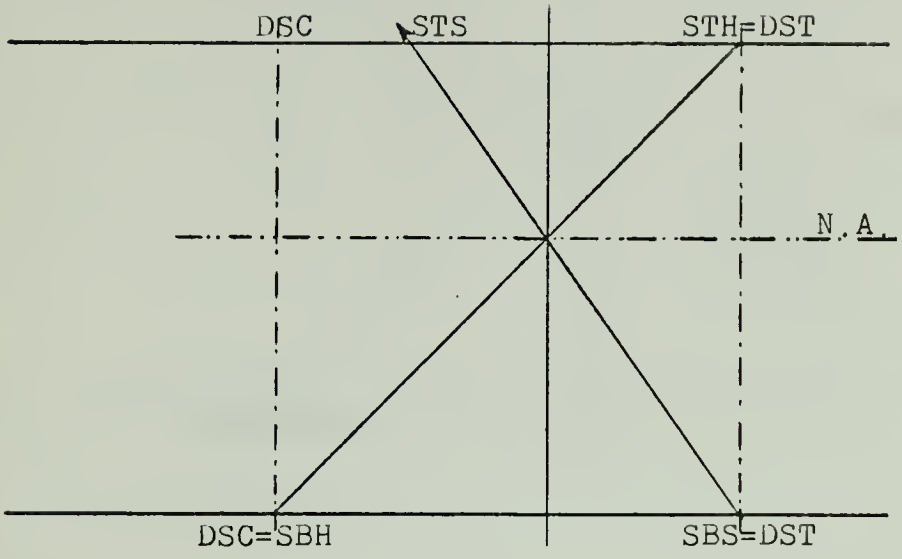
and since I is the same STH can never be of the same magnitude as SBS because

STH = HM*DITOP/I > SBS = SM*DIBOT/I

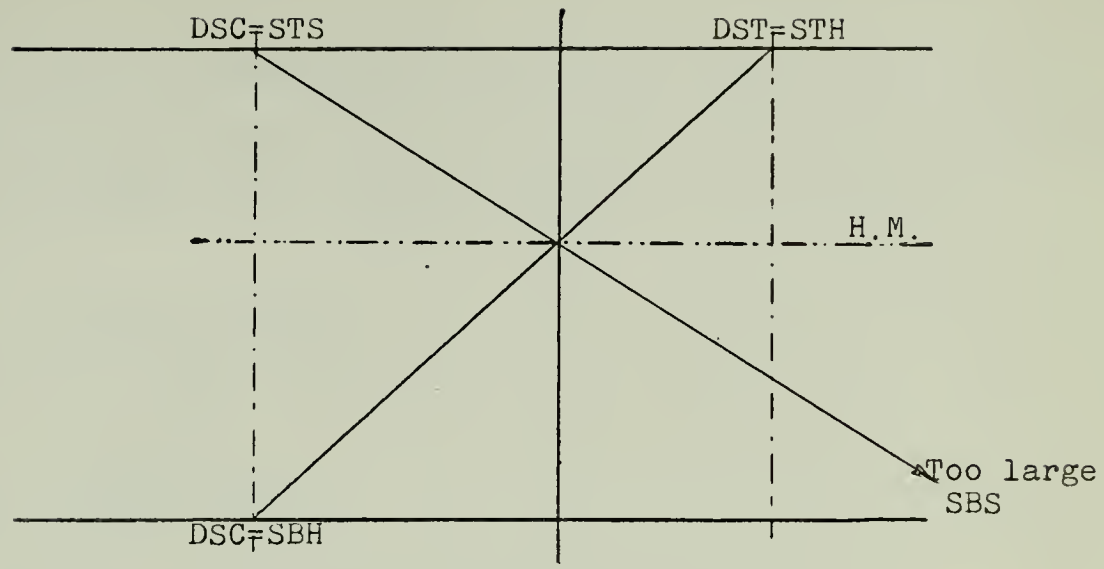
both because DITOP is being set larger than DIBOT and also because we are considering HM > SM to begin with. Thus we are left with the alternative of making DIBOT larger than DITOP to make it possible to satisfy

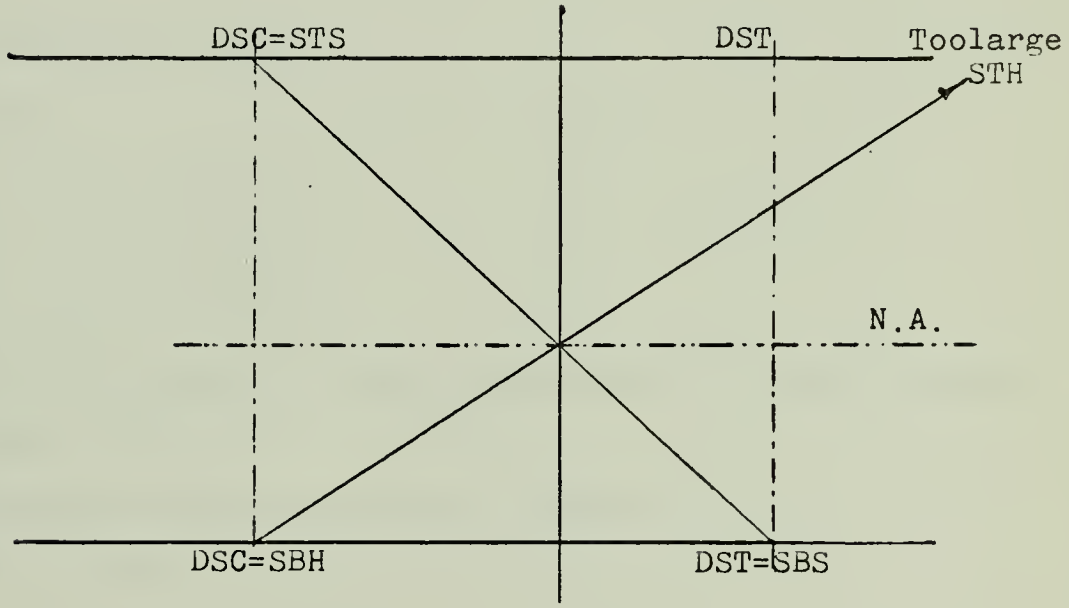
STH = HM*DITOP/I = SBS= SM*DIBOT/I

Thesituation would then be



Besides this is only natural because what we are doing here is to make the material to be stressed to its allowable limit while resisting the larger of the two moments; hogging in this case. This situation will be worked out here as an example and it seems to be quite clear that similarly, cases where SM > HM or DST > DSC or other situation like DST > DSC with HM > SM or DST < DSC with SM > HM could be solved applying a similar reasoning. So, having HM > SM and DSC > DST we should consider the smaller design stress, in this case DST, and have the material stressed to this upper limit. Why?, because if the larger is considered, DSC in this case, there is no way we can have the material stressed to this higher limit in both hogging and sagging while considering the smaller we may attempt to do so. This can be better understood from the two next diagrams.





So, considering the lower design stress, in this case DST, we will stress the material to this maximum in both hogging and sagging thus giving

STH = HM*DITOP/I = DST

SBS = SM*DIBOT/I = DST

Note here that we already know that the neutral axis will

be closer to the top DITOP < DIBOT which means that we must obtain a thickness for the plating at the top larger than at the bottom and so TS=TOP which means that we will be using the following formulas

$$DITOP = \frac{D*(B*BOT+D*TOP)}{P}$$

$$DIBOT = \frac{D*TOP*(B+D)}{P}$$

$$I = \frac{4*D^2*TOP*((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}{P}$$

where $P = (2*D+B)*TOP+B*BOT$

we have also

STH = DST = HM*DITOP/I

SBS = DST = SM*DIBOT/I

SBH = DSC = HM*DIBOT/I

From these three equations we may combine the two first to obtain

HM*DITOP = SM*DIBOT

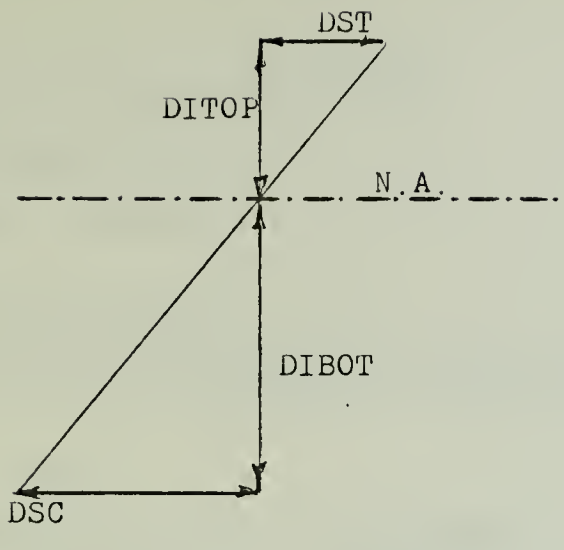
and combining the second and third we obtain

DST*HM = DSC*SM

After combining these two equations we obtain

DST*DIBOT = DSC*DITOP

This equation could have been obtained more easily just by looking at the diagram we are considering and notice the similar triangles



Note also that what we obtain from this equation is to determine the N.A. location by making DITOP and DIBOT proportional to DST And DSC.

Proceeding with this equation we obtain:

$$DST*(D*TOP*(B+D))/P + DSC*(D*B*BOT+D^2*TOP)/P$$

$$TOP*(DST*B+DST*D-DSC*D) = DSC*B*BOT$$

and making

$$AC = DST/DSC+D*(DST-DSC)/(DSC*B)$$

we obtain

$$BOT = AC*TOP$$

We need now an equation to stress the material to its design limit and this can be done by either using

$$STH = DST = HM*DITOP/I$$

or $$SBH = DSC = HM*DIBOT/I$$

From these two equations I prefer to use the second especially because it will simplify the calculations that follow as can be understood from the simpler expression that gives DIBOT as

compared with the one that gives DITOP.

We will then consider here

$$SBH = DSC = HM*DIBOT/I$$

which gives

$$DSC = \frac{HM*D*TOP*(B+D)}{4*D^2*TOP((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}$$

Simplifying we obtain

$$TOP = \frac{HM*(B+D)}{DSC*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D} *BOT$$

or making

$$A = HM*(B+D)/(DSC*4*D*(D^2+2*B*D))$$

$$AB = (3*B^2+2*B*D)/(D^2+2*B*D)$$

we have

$$TOP = A-AB*BOT$$

replacing here

$$BOT = AC*TOP$$

we obtain

$$TOP = \frac{A}{1+AB*AC}$$

Having already found TOP and BOT we may use Bryan's formula to determine S;since the thickness of plating is for this case smaller at the bottom we must consider this thickness and along with it DSC because this will be the larger compressive stress the bottom will be subjected to.

From $$DSC = \frac{E}{0.30396*(1-POI*POI)} * \frac{BOT^2}{S^2}$$

We obtain

$$S = \frac{1}{\sqrt{0.30396*\frac{1-POI*POI}{E}*DSC}}*BOT$$

or making

$$Z = \frac{1}{\sqrt{0.30396*\frac{1-POI*POI}{E}*DSC}}$$

we have

$$S = Z*BOT$$

A computer program was written and applied to two particular sets of dimensions and two different materials namely steel and aluminum. The results are presented next in the computer printouts.

```
C       *AL* IS THE LENGHT
        AL=500.
        B=AL/8.
C       *DRA* IS THE DRAFT
        DRA=B/3.
        D=AL/9.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS IN TENSION
        DST=25000.
C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
        DSC=30000.
C       *HM* IS THE HOGGING BENDING MOMENT
        HM=1.37143*B*DRA*AL*AL
C       *SM* IS THE SAGGING BENDING MOMENT
        SM=B*DRA*AL*AL
        W=0.30396*(1.-POI*POI)*DSC/E
        U=SQRT(W)
        Z=1./U
        A=HM*(B+D)/(DSC*4.**D*(D*D+2.**B*D))
        AB=(3.**B*B+2.*B*D)/(D*D+2.*B*D)
        AC=DST/DSC+D*(DST-DSC)/(DSC*B)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        TOP=A/(1.+AB*AC)
        BOT=AC*TOP
        WRITE(5,10)TOP
   10   FORMAT('1',22X,'TOP=',F10.4)
        WRITE(5,20)BOT
   20   FORMAT(' ',22X,'BOT=',F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*BOT
        WRITE(5,30)S
   30   FORMAT(' ',22X,'S=',F10.4)
        P=2.*D*TOP+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*TOP)/P
        WRITE(5,40)DITOP
   40   FORMAT(' ',18X,'DITOP=',F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*TOP)/P
        WRITE(5,50)DIBOT
   50   FORMAT(' ',18X,'DIBOT=',F10.4)
C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
        GMI=4.*D*D*((2.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
C       *STH* IS THE STRESS ON TOP DUE TO HOGGING
C       *STS* IS THE STRESS ON TOP DUE TO SAGGING
C       *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
 STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                    PAGE    2

A8      C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
A8      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
A8      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
A8              STH=HM*DITOP/GMI
B8              STS=SM*DITOP/GMI
C8              SBH=HM*DIBOT/GMI
D8              SBS=SM*DIBOT/GMI
E8              STCRIT=TOP*TOP*F/(0.3*3*96*S*S*(1.-POI*POI))
F8              SBCRIT=BOT*BOT*F/(0.3*3*96*S*S* 1.-POI*POI))
G8              WRITE(5,60)STH
H4          60  FORMAT(' ',20X,'STH='F10.3)
I0              WRITE(5,70)STS
I4          70  FORMAT(' ',20X,'STS='F10.3)
J0              WRITE(5,80)STCRIT
J4          80  FORMAT(' ',17X,'STCRIT='F10.3)
K0              WRITE(5,90)SBH
K4          90  FORMAT(' ',20X,'SBH='F10.3)
L0              WRITE(5,100)SBS
L4         100  FORMAT(' ',20X,'SBS='F10.3)
M0              WRITE(5,110)SBCRIT
M4         110  FORMAT(' ',17X,'SBCRIT='F10.3)
N8              END
[S] .U          0584[V] AL      0588[V] B       05C4[V] DBA     05CC[V] D
[V] BOT         05DC[V] E       0600[S] .B      05EC[V] DST     05F4[V] DSC
[V] HM          0624[V] SM      0628[V] W       0614[V] U       0630[S] SQRT
[V] Z           061C[V] A       0640[V] AB      0644[V] AC      0648[V] TOP
[V] BOT         01CC[L] 10      0000[S] @I      02C2[L] 20      0650[V] S
[L] 30          0654[V] B       0658[V] DITOP   02C0[L] 40      065C[V] DIBOT
[L] 50          0660[V] GMI     0664[V] STH     0670[V] STS     0674[V] SBH
[V] SBS         067C[V] STCRIT  0680[V] SBCRIT  04E4[L] 60      04BA[L] 70
[L] 80          0528[L] 90      055E[L] 100     0504[L] 110     0000[S] .V
[3          L


PROGRAM LABELS:
0170 *MAIN*     2D8A .V         2BBA .COMP      29DC ALOG       2D98 @I         29F4 .E
0282 .ZERO      2BE0 $6         2734 .A         2CDE .MES       2BEC .W         29E4 EXP
02FA ANINT      27E6 SQRT       2C22 .BARG      2 7F .5         2C54 $8         2C36 .E
0386 .D         2D5C .U         3EB4

ENTRY-POINTS:
02F4 .B         2734 .A         27E6 SQRT       29DC ALOG       29E4 EXP        29FA AI
035C .W         2BBA .COMP      2BE0 $6         2 22 .BARG      2C54 $8         2C7E .5
0282 .ZERO      2C86 .ERCNT     2C88 .D         2CDE .MES       2C68 .U         2D3E .V
0398 @I

COMMON-BLOCKS:
C

UNDEFINED SUBROUTINES:
```

```
      TOP=     3.3464
      BOT=     3.2374
        S=    14.2732
    DITOP=    25.2525
    DIBOT=    31.3030
      STH= 25033.000
      STS= 18223.152
   STCRIT= 63933.609
      SRH= 30016.012
      SRS= 21874.992
   SRCRIT= 29939.961


08 HANDLING CHARGE    $   .25 / JAR          .25
18 LINES PRINTED PR1  $ 1.25 / K LN          .1
80 CARDS READ         $ 1.50 / K CD          .1
00 PLOTTER VECTORS    $   .25 / 1000         .00
19 MODEL 70 SECONDS   $25.00 / HOUR          .1
00 MODEL 85 SECONDS   $12.50 / HOUR          .00
                       TOTAL CHARGE $        .7

EIR 400 14731  LOGGED OUT 04/21/74 20:22.  $    9.05 LEFT AFTER    34 LOGINS.
```

```
      C     *AL* IS THE LENGHT
            AL=5[illegible].
            B=AL/[illegible].
      C     *DRA* IS THE DRAFT
            DRA=[illegible]/[illegible].
            D=AL/[illegible].
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR AL[illegible]
            POI=[illegible].3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR AL[illegible]
            E=1.[illegible]*1[illegible]**6
      C     *DST* IS THE DESIGN STRESS IN TENSION
            DST=[illegible].[illegible].
      C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
            DSC=5.[illegible].
      C     *BM* IS THE LONGITUDINAL BENDING MOMENT
            BM=1.[illegible]/1[illegible]*DRA*AL*AL
      C     *SM* IS THE SAGGING BENDING MOMENT
            SM=[illegible]*[illegible]*AL*AL
            A=.2[illegible]/(1.-POI-POI)*DSC/E
            C=SQRT(A)
            Z=1./C
            A=BM*([illegible])/(DSC*4.*[illegible]*(D+D+2.*B*D))
            AB=(3.*[illegible]+3.*B*B)/(D*D+2.*B*D)
            AC=DST/DSC+D*(DST+DSC)/(DSC*B)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            TOP=A/(1.+[illegible]*AC)
            BOT=AC*TOP
            WRITE(5,1[illegible])TOP
         10 FORMAT(' ',3X,'TOP='F12.4)
            WRITE(5,2[illegible])BOT
         20 FORMAT(' ',4X,'BOT='F1[illegible].4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=Z*PI/T
            WRITE(5,3[illegible])S
         30 FORMAT(' ',22X,'S='F10.4)
            P=2.*[illegible]*TOP+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B+3*BOT+D*TOP)/P
            WRITE(5,4[illegible])DITOP
         40 FORMAT(' ',1[illegible]X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B+TOP+D*TOP)/P
            WRITE(5,5[illegible])DIBOT
         50 FORMAT(' ',1[illegible]X,'DIBOT='F12.4)
      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
            GMI=4.*[illegible]*D.((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
      C     *STS* IS THE STRESS ON TOP DUE TO SAGGING
      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
C      *SBS* IS THE STRESS DUE TO SAGGING
C      *STC*IT* IS THE CRITICAL STRESS ON TOP
C      *SBC*IT* IS THE CRITICAL STRESS ON BOT
       STH=W*H*IT**2/6.0*I
       STS=W*H*IT**2/6.0*I
       SBH=W*H*(D-IT)**2/6.0*I
       SBS=W*H*(D-IT)**2/6.0*I
       STCRIT=IT*E/(.3696*S*S*(1.+POI*POI))
       SBCRIT=(D-IT)*E/(.3696*S*S*(1.+POI*POI))
       WRITE(6,5)STH
    60 FORMAT(' ',2X,'STH=',F10.3)
       WRITE(6,7)STS
    70 FORMAT(' ',2X,'STS=',F10.3)
       WRITE(6,8)STCRIT
    80 FORMAT(' ',17X,'STC IT=',F10.3)
       WRITE(6,9)SBH
    90 FORMAT(' ',2X,'SBH=',F10.3)
       WRITE(6,10)SBS
   100 FORMAT(' ',2X,'SBS=',F10.3)
       WRITE(6,11)SBCRIT
   110 FORMAT(' ',17X,'SBC IT=',F10.3)
       END
```

```
.U      25A4[L]  .L      2BC0[V]  B       25C4[V]  DEA     25CC[V]  D
.POI    2BDC[L]  F       2[S]     .W      25E8[V]  DS1     25F0[V]  DSC
.N      5.0[V]   SH      2[S]     W       2601[V]  U       2614[S]  SQRT
Z       2615[V]  S       2630[V]  AF      2641[V]  AC      2644[V]  TOP
BOT     2100[L]  1.      2[S]     @I      0202[L]  20      264C[V]  S
SW      2651[V]  F       2[S]     DITOP   0210[L]  40      2654[V]  DIRCT
SW      2658[V]  .H      2644[V]  STH     264C[V]  STS     2671[V]  SBH
SBS     267A[V]  SBCRIT  2677[V]  SBCRIT  0484[L]  60      249A[L]  70
.V      2528[L]  1.      2552[L]  1.2     0594[L]  110     2[S]     .V
```

L

LABELS:

```
.7   *MAIN*   2D5A .V      2BA6 .COMP    2BD8 ALOG    2D94 @I      26F0 .R
BOT  .ZERO    2B1C 66      2732 .A       2CDA .MES    2B58 .W      29E0 EXP
.E   AINT     2762 SQRT    2C1E .RAFG    2C7A .5      2C50 $8      2C32 .EP
2C   .O       2C58 .L      3EA0
```

ENTRY POINTS:

```
.R       273A .W      2732 SQRT    2BD8 ALOG    29E0 EXP     2AE6 AIN
.W       2BA6 .COMP   2B0C $A      2C1E .RAFG   2C50 $8      2C7A .5
.ZERO    2C32 .EPOINT 2C34 .O      2CDA .MES    2D64 .U      2D8A .V
2D94 @I
```

COMMON BLOCKS:

EXTERNAL SUBROUTINES:

```
                TCP=        .3464
                HTT=        .8374
                  S=        .8270
              DITTO=      28.2525
              DIRCT=        .3473
                 ST=        .0000
                 ST=    1 22.9.15
             STORIT=        .7285
                 SI=        .7170
                 SI=    1974.5500
             SLORIT=        .1350


   HANDLING CHARGE                .35 /  JOB          .35
   LINES PRINTED                 1.25 /  K LI         .15
   CARDS READ                    1.5  /  K CI         .12
   LOTT - VECTORS                 .05 /  1.0          .00
   TOPL 72 SECONDS               5.0  /  HOUR         .10
   COPL 67 SECONDS               12.5  /  HOUR         .00
                                 TOTAL  0.4.85 $      .72


   490 14731  LOGGED OUT  4/21/74 20:20.  $    9.80 LEFT AFTER    33 LOGINS.
```

```
0004      C     *AL* IS THE LENGHT
0004            AL=1000.
000C            B=AL/5.75
0018      C     *DRA* IS THE DRAFT
0018            DRA=B/3.3
0024            D=AL/14.
0030      C     *POI* IS THE POISSON'S RATIO O  THE MATERIAL
0030      C     FOR STEEL
0030            POI=0.3
0038      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038      C     FOR STEEL
0038            E=30.*10.**6
0040      C     *DST* IS THE DESIGN STRESS IN TENSION
0040            DST=25000.
0054      C     *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054            DSC=30000.
005C      C     *HM* IS THE HOGGING BENDING MOMENT
005C            HM=1.37143*B*DRA*AL*AL
0074      C     *SM* IS THE SAGGING BENDING MOMENT
0074            SM=B*DRA*AL*AL
0088            W=0.30396*(1.-POI*POI)*DSC/E
00A8            U=SQRT(W)
00B4            Z=1./U
00C0            A=HM*(B+D)/(DSC*4.*D*(D*D+2.*B*D))
00FC            AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
0158            AC=DST/DSC+D*(DST-DSC)/(DSC*B)
018C      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
018C      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
018C            TOP=A/(1.+AB*AC)
01A4            BOT=AC*TOP
01B0            WRITE(5,10)TOP
01CC        10  FORMAT('1',20X,'TOP=',F10.4)
01EA            WRITE(5,20)BOT
0202        20  FORMAT(' ',20X,'BOT=',F10.4)
021C      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
021C            S=Z*BOT
0238            WRITE(5,30)S
0244        30  FORMAT(' ',22X,'S=',F10.4)
025C            P=2.*D*TOP+B*(TOP+BOT)
0280      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
0280            DITOP=D*(B*BOT+D*TOP)/P
02A4            WRITE(5,40)DITOP
02C0        40  FORMAT(' ',18X,'DITOP=',F10.4)
02DC      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
02DC            DIBOT=D*(B*TOP+D*TOP)/P
0300            WRITE(5,50)DIBOT
031C        50  FORMAT(' ',18X,'DIBOT=',F10.4)
0338      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
0338            GMI=4.*B*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
03A8      C     *STH* IS THE STRESS ON TOP DUE TO HOGGING
03A8      C     *STS* IS THE STRESS ON TOP DUE TO SAGGING
03A8      C     *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

```
1BA8      C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
1BA8      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
1BA8      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
1BA8              STH=HM*DITOP/GMI
1BB8              STS=SM*DITOP/GMI
1BC8              SBH=HM*DIBOT/GMI
1BD8              SBS=SM*DIBOT/GMI
1BE8              STCRIT=TOP*TOP*F/(0.3E306*S*S*(1.-POI*POI))
1C28              SBCRIT=BOT*BOT*F/(0.3E306*S*S*(1.-POI*POI))
1C68              WRITE(5,60)STH
1C84        60    FORMAT(' ',20X,'STH='F10.3)
1C9E              WRITE(5,70)STS
1CBA        70    FORMAT(' ',20X,'STS='F10.3)
1CD4              WRITE(5,80)STCRIT
1CF0        80    FORMAT(' ',17X,'STCRIT='F10.3)
1D2C              WRITE(5,90)SBH
1D28        90    FORMAT(' ',20X,'SBH='F10.3)
1D42              WRITE(5,100)SBS
1D5F       100    FORMAT(' ',20X,'SBS='F10.3)
1D78              WRITE(5,110)SBCRIT
1D94       110    FORMAT(' ',17X,'SBCRIT='F10.3)
1DB0              END
A[S] .U         A584[V] AL      A58C[V] B       A5C4[V] DRA     A5CC[V] D
A[V] POI        A5DC[V] E       A620[S] .R      A5EC[V] DST     A5F4[V] DSC
A[V] HM         A604[V] SM      A608[V] W       A614[V] U       A630[S] SQRT
A[V] Z          A61C[V] A       A640[V] AB      A648[V] AC      A64C[V] TOP
A[V] BOT        A1CC[L] 10      A200[S] @I      A2C2[L] 20      A654[V] S
A[L] 30         A658[V] B       A65C[V] DITOP   A2C2[L] 40      A660[V] DIBOT
A[L] 50         A664[V] GMI     A670[V] STH     A674[V] STS     A678[V] SBH
A[V] SBS        A680[V] STCRIT  A684[V] SBCRIT  A4C4[L] 60      A4BA[L] 70
A[L] 80         A528[L] 90      A55E[L] 100     A5C4[L] 110     A207[S] .V
REQ           L


PROGRAM LABELS:
A270 *MAIN*     2D8E .V         2BBE .COMP      29E0 ALOG       2D9C @I         26F8 .B
2C86 .7ERO      2BF4 $4         2738 .A         27E2 .MES       2B60 .W         29E8 EXP
2AEE ALNT       27EA SQRT       2C26 .BARG      2C82 .5         2C58 $8         2C8A .E
2CBA .N         2D60 .U         3EB8

ENTRY-POINTS:
26F8 .B         2738 .A         27EA SQRT       29E0 ALOG       29E8 EXP        2AEE ALNT
2B60 .W         2BBE .COMP      2BE4 $4         2C26 .BARG      2C58 $8         2C82 .5
2C86 .7ERO      2C8A .ERCNT     2C8C .N         2CE2 .MES       2D6C .U         2D92 .V
2D9C @I

COMMON-BLOCKS:
BE

UNDEFINED SUBROUTINES:
```

```
          TOP=     3.0399
          BOT=     2.3252
            S=   139.8065
        DITOP=    32.4675
        DIBOT=    38.9610
          STH= 25000.000
          STS= 18220.152
       STCRIT= 51278.250
          SBH= 29990.996
          SBS= 21874.084
       SBCRIT= 29990.961


JOB HANDLING CHARGE     $   .35 / JOB          .35
118 LINES PRINTED PR1   $ 1.25 / K LN          .15
 80 CARDS READ          $ 1.50 / K CD          .12
 00 PLOTTED VECTORS     $   .25 / 1000         .0
 14 MODEL 70 SECONDS    $25.00 / HOUR          .1
 00 MODEL 80 SECONDS    $12.50 / HOUR          .0
                        TOTAL CHARGE $         .72

EIR 400 14731  LOGGED OUT 04/21/77 20:27.  $   7.58 LEFT AFTER    26 LOGINS.
```

```
0004     C      *AL* IS THE LENGHT
0004            AL=1000.
000C            B=AL/5.75
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.3
0024            D=AL/14.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR ALUMINUM
0030            POI=0.33
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR ALUMINUM
0038            E=10.*10.**6
0040     C      *DST* IS THE DESIGN STRESS IN TENSION
0040            DST=25000.
0054     C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054            DSC=30000.
0060     C      *HM* IS THE HOGGING BENDING MOMENT
0060            HM=1.37143*B*DRA*AL*AL
0074     C      *SM* IS THE SAGGING BENDING MOMENT
0074            SM=B*DRA*AL*AL
0088            V=0.30396*(1.-POI*POI)*DSC/E
0098            U=SQRT(V)
00B4            Z=1./U
00C8            A=HM*(B+D)/(DSC*4.*D*(D*D+2.*B*D))
00DC            AB=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
00F8            AC=DST/DSC+D*(DST-DSC)/(DSC*B)
0108     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
0108     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0108            TOP=A/(1.+AB*AC)
0114            BOT=AC*TOP
0120            WRITE(5,10)TOP
012C        10  FORMAT('1',20X,'TOP=',F10.4)
013E            WRITE(5,20)BOT
0152        20  FORMAT(' ',20X,'BOT=',F10.4)
0168     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0168            S=Z*BOT
0178            WRITE(5,30)S
0184        30  FORMAT(' ',20X,'S=',F10.4)
0198            P=2.*D*TOP+B*(TOP+BOT)
01B0     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
01B0            DITOP=D*(B*BOT+D*TOP)/P
01C4            WRITE(5,40)DITOP
01D0        40  FORMAT(' ',18X,'DITOP=',F10.4)
01DC     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
01DC            DIBOT=D*(B*TOP+D*TOP)/P
01F0            WRITE(5,50)DIBOT
01FC        50  FORMAT(' ',18X,'DIBOT=',F10.4)
0218     C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
0218            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
0248     C      *STH* IS THE STRESS ON TOP DUE TO HOGGING
0248     C      *STS* IS THE STRESS ON TOP DUE TO SAGGING
0248     C      *SBH* IS THE STRESS ON BOT DUE TO HOGGING
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
3AR      C       *SBS* IS THE STRESS ON BOT DUE TO SAGGING
3AR      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
3AR      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
3AR              STH=HM*DITOP/GMI
3B8              STS=SM*DITOP/GMI
3C8              SBH=HM*DIBOT/GMI
3D8              SBS=SM*DIBOT/GMI
3E8              STCRIT=TOP*TOP*F/(0.3*396*S*S*(1.-POI*POI))
428              SBCRIT=BOT*BOT*F/(0.3*396*S*S*(1.-POI*POI))
468              WRITE(5,60)STH
484          60  FORMAT(' ',23X,'STH=',F10.3)
49E              WRITE(5,70)STS
4BA          70  FORMAT(' ',23X,'STS=',F10.3)
4D4              WRITE(5,80)STCRIT
4F0          80  FORMAT(' ',17X,'STCRIT=',F10.3)
50C              WRITE(5,90)SBH
528          90  FORMAT(' ',23X,'SBH=',F10.3)
542              WRITE(5,100)SBS
55E         100  FORMAT(' ',23X,'SBS=',F10.3)
578              WRITE(5,110)SBCRIT
594         110  FORMAT(' ',17X,'SBCRIT=',F10.3)
5B0              END
```

```
*(S) .U          @5B4(V) AL       @5BC(V) B        @5C4(V) DRA      @5CC(V) D
.(V) DOI         @5DC(V) E        @5E8(S) .B       @5F3(V) DST      @5FB(V) DSC
=(V) HM          @600(V) SM       @604(V) W        @61A(V) U        @623(S) SQRT
 (V) Z           @61E(V) A        @63C(V) AB       @644(V) AC       @649(V) TOP
-(V) BOT         @1CC(L) 10       @200(S) @I       @22A(L) 20       @245(V) S
.(L) 30          @654(V) P        @658(V) DITOP    @22A(L) 40       @25C(V) DIBOT
-(L) 50          @660(V) GMI      @66C(V) STH      @674(V) STS      @67A(V) SBH
-(V) SBS         @67C(V) STCRIT   @688(V) SBCRIT   @694(L) 60       @6BA(L) 70
*(L) 80          @528(L) 90       @55E(L) 100      @5B4(L) 110      @20A(S) .V
*EQ          L
```

```
*GRAM LABELS:
2070 *MAIN*    2D8A .W        2BBA .COMP     28DC ALOG      2D98 @I        26E4 .B
2C82 .7ERO     2BE0 $4        2734 .A        2CDF .MES      2B5C .W        29E4 EX
DAFA AINT      27E6 SQRT      2C22 .BARG     2C7E .5        2C54 $8        2C86 .E
2C86 .O        2D5C .U        3E94

*RY-POINTS:
26E4 .B        2734 .A        27E6 SQRT      28DC ALOG      29E4 EXP       2AEA AI
2BEC .W        2BBA .COMP     2BE0 $4        2C22 .BARG     2C54 $8        2C7E .5
2C82 .7ERO     2C86 .ERCNT    2C98 .O        2CDF .MES      2D68 .U        2D9E ./
2D98 @I

*MON-BLOCKS:
*E


EFINED SUBROUTINES:
```

```
      TOP=     3.0799
      BOT=     3.3252
        S=    81.5687
    DITOP=    32.4475
    DIBOT=    38.9619
      STH= 25030.203
      STS= 18225.152
   STCRIT=  5127.383
      SBH= 29999.996
      SBS= 21874.984
   SBCRIT= 30000.035


08 HANDLING CHARGE    $  .35 / JOB          .35
18 LINES PRINTED PR1  $ 1.25 / K LN         .15
80 CARDS READ         $ 1.50 / K CD         .12
00 PLOTTER VECTORS    $  .25 / 1000         .0
19 MODEL 70 SECONDS   $25.00 / HOUR         .1
00 MODEL 80 SECONDS   $12.50 / HOUR         .0
                   TOTAL CHARGE =           .7

FIR 490 14731  LOGGED OUT 04/21/74 20:24.  $    8.30 LEFT AFTER     35 LOGINS.
```

HOGGING MOMENT AND SAGGING MOMENT OF EQUAL MAGNITUDE DESIGN STRESS IN TENSION AND DESIGN STRESS IN COMPRESSION OF EQUAL VALUE; LATERAL LOAD ALSO CONSIDERED

The lateral load being here considered will be a "head" of salt water of eight feet on the top plating (HTOP=8 ft) and a "head" of salt water equal to the draft on the bottom plating (HBOT=DRA).

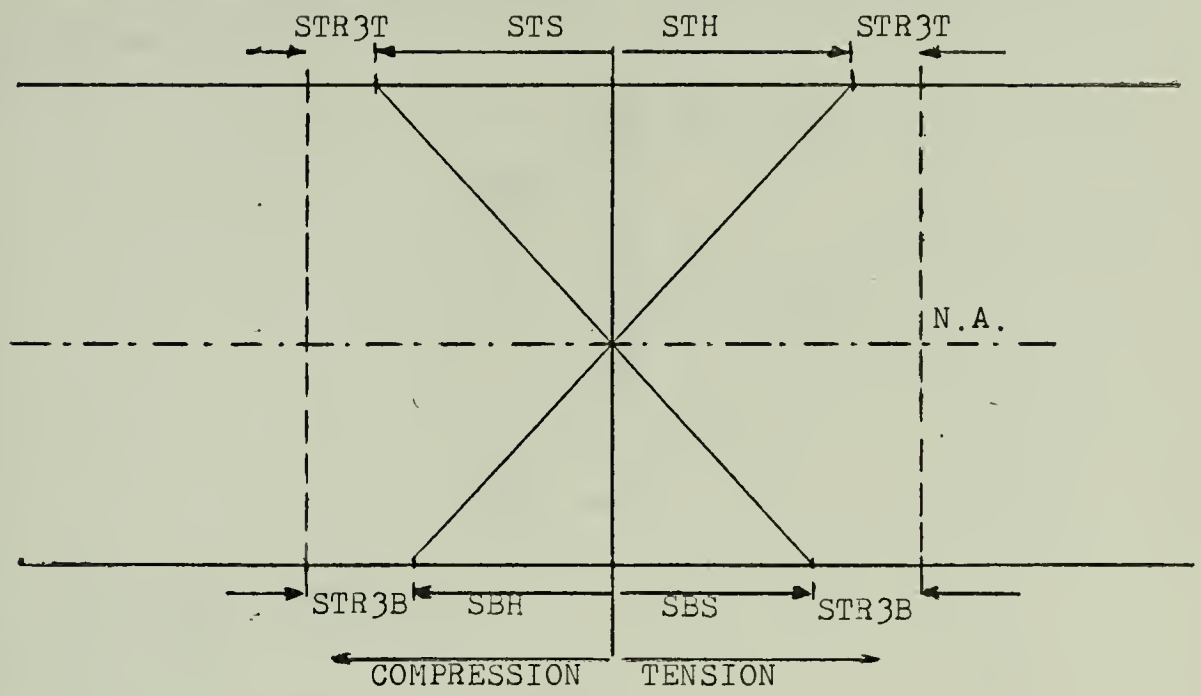
We will use here the simplified approach as suggested in the following note; this simplified approach is at least conservative.

Note: Bleich, from his experiments and theoretical studies on the effect of normal pressure in the buckling strength of thin panels, concluded that the buckling strength is increased when combined with a sufficiently large normal load, and that the increase is greater for thesimply supported edges situation than with fixed edges. For heavier plating , where thedeflection does not exceed half of the plating thickness, the increase in buckling strength resulting from normal load is negligible. It was therefore suggested, for simplicity, that the critical stress be computed for in plane loading only.

The tertiary stresses we are interested in considering here are those exerted at points B directed longitudinally; these will combine with the longitudinal bending stresses or primary stresses as described in a previous section.

Since now we have DST=DSC and HM=SM=BM we may think of

a diagram for the stress distributions as indicated next figure:



From this diagram we may understand that the neutral axis should be located closer to the bottom which means that the thickness at the bottom will be larger than at the top BOT > TOP . So, we may already write the following formulas where TS was replaced by BOT

$$DITOP = D*(B+D)*BOT/P$$

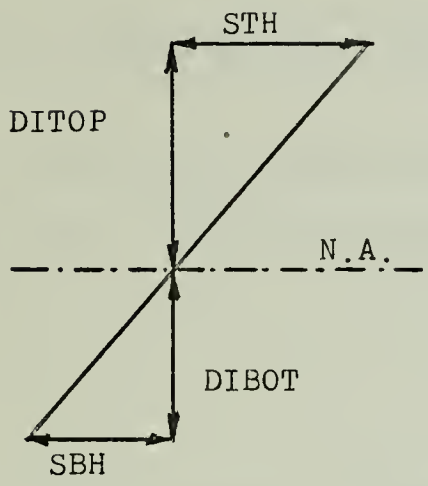
$$DIBOT = D*(B*TOP+D*BOT)/P$$

$$I = 4*D*D*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)*BOT/P$$

where

$$P = 2*D*BOT+B*(TOP+BOT)$$

We may now think of the following relationships to determine TOP and BOT.



$$STH*DIBOT = SBH*DITOP$$

or knowing that

$$STR3T = 0.152222*HTOP*\left(\frac{S}{TOP}\right)^2$$

$$STR3B = 0.152222*HBOT*\left(\frac{S}{BOT}\right)^2$$

and anticipating

$$S = Z*TOP$$

where

$$Z = 1/\left(\sqrt{0.30396*\frac{1-POI*POI}{E}*DST}\right)$$

we have

$$Z^2 = \left(\frac{S}{TOP}\right)^2$$

If we now make $\left(\frac{S}{BOT}\right)^2 = Z^2$

in order to simplify the equations, we see that when we do this, since

$$(\frac{S}{BOT})^2 < (\frac{S}{TOP})^2$$

we are increasing the value of STR3B and this means that since

DST = SBH+STR3B

we are decreasing"slightly" the value of SBH that could be allowed to reach a larger value; so , the substitution

$$(\frac{S}{BOT})^2 = Z^2$$

is on the safe side and has the advantage of simplifying the equations considerably.

So we may write

STH = DST-STR3T

SBH = DST-STR3B

STR3T = 0.152222*HTOP*Z^2

STR3B = 0.152222*HBOT*Z^2

A = DST-STR3T

AB = DST-STR3B

so

A*DIBOT = AB*DITOP

and we obtain replacing DITOP and DIBOT by their equations, and simplifying

$$TOP = \frac{AB*(B+D)-A*D}{A*B}*BOT$$

or making

AC = (AB*(B+D)-A*D)/(A*B)

we finally obtain

TOP = AC*BOT

Now in order to stress the material to its design stress we may either consider STH, STS, SBH, SBS.

Due to ease of calculation we may either choose STS or STH; the expressions will be exactly the same. I will consider here

STH = BM*DITOP/I

and

STH = DST-STR3T = A

Substituting for DITOP and I we obtain

$$A = \frac{BM*D*(B+D)*BOT}{4*D^2*BOT*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)}$$

and after simplifying we arrive at

$$BOT = \frac{BM*(B+D)}{A*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*TOP$$

Making

AD = BM*(B+D)/(A*4*D*(D^2+2*B*D))

AE = (3*B^2+2*B*D)/(D^2+2*B*D)

we obtain

BOT = AD-AE*TOP

substituting

$$TOP = AC*BOT$$

we obtain

$$BOT = \frac{AD}{1+AC*AE}$$

Considering now the instability formula (BRYAN) we notice that since the top will have the thinner plating we will consider TOP stressed to the maximum allowed DST.

So we start with

$$Z = 1/\left(\sqrt{0.30396*\frac{1-POI*POI}{E}}*DST\right)$$

$$S = Z*TOP$$

The total stresses will then be given by

$$TSTH = BM*DITOP/I+STR3T$$

$$TSTS = BM*DITOP/I+STR3T$$

$$TSBH = BM*DIBOT/I+0.152222*HBOT*S^2/BOT^2$$

$$TSBS = BM*DIBOT/I+0.152222*HBOT*S^2/BOT^2$$

The computer printouts for the same cases analysed in theprevious section are presented next.

```
0004     C      *AL* IS THE LENGHT
0004            AL=500.
000C            B=AL/8.
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.
0024            D=AL/9.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR STEEL
0030            POI=0.3
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR STEEL
0038            E=30.*12.**6
004C     C      *DST* IS THE DESIGN STRESS
004C            DST=25000.
0054     C      *BM* IS THE BENDING MOMENT
0054            BM=1.37143*B*DRA*AL*AL
006C            W=0.30396*(1.-POI*POI)*DST/E
008C            U=SQRT(W)
0098            Z=1./U
00A4            *HTOP* IS THE HEAD OF WATER ON DECK
00A4            HTOP=8.
00AC            *HBOT* IS THE  HEAD OF WATER ON BOTTOM
00AC            HBOT=DRA
00B4            STR3T=0.152222*HTOP*Z*Z
00C8            STR3B=0.152222*HBOT*Z*Z
00DC            A=DST-STR3T
00E8            AB=DST-STR3B
00F4            AC=(AB*(B+D)-A*D)/(A*B)
012C            AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
0178            AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
01C4     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
01C4     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01C4            BOT=AD/(1.+AC*AE)
01DC            TOP=AC*BOT
01E8            WRITE(5,10)TOP
0204        10  FORMAT('1',20X,'TOP='F10.4)
021E            WRITE(5,20)BOT
023A        20  FORMAT(' ',20X,'BOT='F10.4)
0254     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0254            S=Z*TOP
0260            WRITE(5,30)S
027C        30  FORMAT(' ',22X,'S='F10.4)
0294            P=2.*D*BOT+B*(TOP+BOT)
02B8     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02B8            DITOP=D*(B*BOT+D*BOT)/P
02DC            WRITE(5,40)DITOP
02F8        40  FORMAT(' ',18X,'DITOP='F10.4)
0314     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0314            DIBOT=D*(B*TOP+D*BOT)/P
0338            WRITE(5,50)DIBOT
0354        50  FORMAT(' ',18X,'DIBOT='F10.4)
0370     C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
. STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                    PAGE  2

1070          GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
13E0     C    *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
13E0     C    *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
13E0     C    *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
13E0     C    *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
13E0     C    *STCRIT* IS THE CRITICAL STRESS ON TOP
13E0     C    *SBCRIT* IS THE CRITICAL STRESS ON BOT
13E0          TSTH=BM*DITOP/GMI+STR3T
13F4          TSTS=BM*DITOP/GMI+STR3T
1408          STCRIT=TOP*TOP*E/(0.3@396*S*S*(1.-POI*POI))
1448          WRITE(5,60)TSTH
1464       60 FORMAT(' ',19X,'TSTH=',F10.3)
147E          WRITE(5,70)TSTS
149A       70 FORMAT(' ',19X,'TSTS=',F10.3)
14B4          WRITE(5,80)STCRIT
14D0       80 FORMAT(' ',17X,'STCRIT='F10.3)
14EC          TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
1528          TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
1564          SBCRIT=BOT*BOT*E/(0.3@396*S*S*(1.-POI*POI))
15A4          WRITE(5,90)TSBH
15C0       90 FORMAT(' ',19X,'TSBH=',F10.3)
15DA          WRITE(5,100)TSBS
15F6      100 FORMAT(' ',19X,'TSBS=',F10.3)
1610          WRITE(5,110)SBCRIT
162C      110 FORMAT(' ',17X,'SBCRIT='F10.3)
1648          END
@[S] .U       064C[V] AL      0654[V] B       06EC[V] DRA     0664[V] D
C[V] POI      0674[V] E       0000[S] .R      0684[V] DST     068C[V] BM
4[V] W        06A0[V] U       0000[S] SQRT    06A4[V] Z       06A8[V] HTOP
C[V] HBOT     06B0[V] STR3T   06B8[V] STR3B   06BC[V] A       06C0[V] AB
4[V] AC       06D8[V] AD      06EC[V] AE      06F0[V] BOT     06F4[V] TOP
4[L] 10       0000[S] @I      023A[L] 20      06F8[V] S       027C[L] 30
C[V] P        0700[V] DITOP   02F8[L] 40      0704[V] DIBOT   0354[L] 50
8[V] GMI      0714[V] TSTH    0718[V] TSTS    071C[V] STCRIT  0464[L] 60
A[L] 70       04D0[L] 80      0720[V] TSBH    0724[V] TSBS    0728[V] SBCRIT
@[L] 90       05F6[L] 100     062C[L] 110     0000[S] .V
XEQ          L
F


OGRAM LABELS:
2070 *MAIN*   2EB2 .V      2CE2 .COMP    2984 ALOG     2EC0 @I       279C .F
2DAA .ZERO    2D08 $6      27DC .A       2E06 .MES     2C84 .W       2A8C E
2C12 AINT     288E SQRT    2D4A .RARG    2DA6 .5       2A8C AEXP     2DAE .F
2D7C $8       2DAE .0      2E84 .U       3FDC

TRY-POINTS:
279C .R       27DC .A      288E SQRT     2984 ALOG     2A8C AEXP     2A8C E
2C12 AINT     2C84 .W      2CE2 .COMP    2D08 $6       2D4A .RARG    2D7C $
2DA6 .5       2DAA .ZERO   2DAE .ERCNT   2DB0 .0       2E06 .MES     2E90 .I
2EB6 .V       2EC0 @I
```

```
          TOP=     0.1671
          BOT=     0.8383
            S=    11.0049
        DITOP=    35.3820
        DIBOT=    20.1736
         TSTH= 25000.012
         TSTS= 25000.012
       STCRIT= 25000.000
         TSBH= 11728.668
         TSBS= 11728.668
       SBCRIT=706635.250
END

F VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/27/74


JOB HANDLING CHARGE    $  .35 / JOB          .35
125 LINES PRINTED PR1  $ 1.25 / K LN         .16
 84 CARDS READ         $ 1.50 / K CD         .13
 00 PLOTTER VECTORS    $  .25 / 1000         .00
 15 MODEL 70 SECONDS   $25.00 / HOUR         .10
 00 MODEL 85 SECONDS   $12.50 / HOUR         .00
                        TOTAL CHARGE $       .74


PEIR 490 14731  LOGGED OUT 04/29/74 18:35.  $  33.19 LEFT AFTER    42 LOGINS.
```

Note here that because we have in this run BOT>> TOP the approximation made to simplify the formulas, namely

$$Z = \frac{S}{BOT}$$

becomes very inaccurate compared to what the actual value should be

$$Z = \frac{S}{TOP}$$

this is the cause for obtaining such low stresses at the bottom. We might refine the result for this case as is done for the "1000 ft steel case" also included in this section which presented still another difficulty. Since all steps to have the bottom stressed to DST are explained in detail for such case they will be omited here.

```
C       *AL* IS THE LENGHT
        AL=500.
        B=AL/20.
C       *DRA* IS THE DRAFT
        DRA=B/3.
        D=AL/20.
C       *AI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR ALUMINUM
        POI=.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR ALUMINUM
        E=10.**7 .***6
C       *DST* IS THE DESIGN STRESS
        DST=2500.
C       *DI* IS THE BENDING MOMENT
        DI=1.3714E-6*DRA*AL**4
        W=.2500*(1.-POI**2)*DST/E
        H=SQRT(W)
        Z=1./H
        *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=2.
        *HBOT* IS THE HEAD OF WATER ON BOTTOM
        HBOT=DRA
        ST1=1.1582E-6*TOP*Z*Z
        ST2=1.1582E-6*BOT*Z*Z
        A=DST-ST1-ST2
        AM=DST-ST1
        AC=(AM*(1.+H)**4)/(A*H)
        AD=-M*(1.+H)/(A*(4.+2.*H+(H**2+2.*H*H)))
        AB=(3.*H**3+2.*H**2)/(1.*H**3+2.*H**2)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AD/(1.+AC+AB)
        TOP=AC*BOT
        WRITE(5,10)TOP
   10   FORMAT('1',22X,'TOP='F10.4)
        WRITE(5,20)BOT
   20   FORMAT(' ',22X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
   30   FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+2*BOT)/P
        WRITE(5,40)DITOP
   40   FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+2*BOT)/P
        WRITE(5,50)DIBOT
   50   FORMAT(' ',18X,'DIBOT='F10.4)
C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

STRENGHT OF SHIPS-ON THE EQUATORIAL AXIS LOCATION PAGE 2

```
                GMI=4.*G*D*((3.*B*C+2.*(B*D)*TOP*BOT+(D*D+2.*B*C)*BOT*BOT)/P
      C         *ISTM*IS THE STRESS ON TOP DUE TO BOGGING
      C         *ISTS*IS THE STRESS ON TOP DUE TO SAGGING
      C         *ISBM*IS THE STRESS ON BOT DUE TO BOGGING
      C         *ISBS*IS THE STRESS ON BOT DUE TO SAGGING
      C         *STCRIT IS THE CRITICAL STRESS ON TOP
      C         *SBCRIT IS THE CRITICAL STRESS ON BOT
                TSTM=MI*DITOP/GI+ST*ST
                TSTC=MI*DITOP/GI+ST*ST
                STCRIT=1.E6*TS*E/(1.-3*6*S*S*(1.-POI*POI))
                WRITE(6,60)TSTM
   60         FORMAT(' ',13X,'TSTM=',F10.3)
                WRITE(6,70)TSTS
   70         FORMAT(' ',13X,'TSTS=',F10.3)
                WRITE(6,80)STCRIT
   80         FORMAT(' ',13X,'STCRIT=',F10.3)
                TSBM=-MI*DIBOT/GI+ST*1E6/22.22*HBOT*S*C/(BOT*BCT)
                TSBS=-MI*DIBOT/GI+ST*1E6/22.22*HBOT*S*E/(BOT*BCT)
                SBCRIT=1.E6*E/(1.-3*6*S*S*(1.-POI*POI))
                WRITE(6,90)TSBM
   90         FORMAT(' ',13X,'TSBM=',F10.3)
                WRITE(6,100)TSBS
  100         FORMAT(' ',13X,'TSBS=',F10.3)
                WRITE(6,110)SBCRIT
  110         FORMAT(' ',13X,'SBCRIT=',F10.3)
                END
```

```
 [S] .V          44C[V] AL          4F4[V] B          6B0[V] DRA        0664[V] D
 [V] P*I         674[V] E           7C0[S] .P         0C6*[V] DST       0638[V] EM
 [V] .           69C[V] M           A00[S] GBFT       0C6 [V] Z         0A44[V] HTOP
 [V] M  IT       6AC[V] STBIT       6F4[V] STMB       0C6 [V] A         0BBC[V] AB
 [V] AC          4D4[V] AC          6E8[V] AE         0C6 C[V] BOT      0F22[V] TOP
 [L] 1           0 0[S]  I          23C[L] 2          0C64[V] S         127C[L] 3
 [V] P           24FC[V] DITOP      2F0[L] 4          07 0[V] DJBOT     1354[L] 5
 [V] G T         07 [V] ISTM        714[V] ISTS       07F8[V] STCRIT    1464[L] 6
 [L] 7           040C[L] 8          71C[V] TSBM       07FC[V] TSBS      0724[V] SBCRIT
 [L] 9           0BF8[L] 10         82C[L] 11         00 [S] .V
 ND          L
```

```
PROGRAM LABELS:
0070 *.I*  2D4E .V        2CDE .CCMP      2980 ALOG      2EBC @I        2798 .
2DA6 .2EF0 2C04 SQ        2708 .A         2E42 .MES      2C8C .W        2A88 E
2C0E ABSIT 2F8A S  T      2E4A .SARG      2DA2 .5        2A8E AEXP      2DAA .
2078 $     2E7A .         2E3C .          3FD8

TRY-POINTS:
2798 .     27D8 .M        2E3A SQRT       2980 ALOG      2A8E AEXP      2A88 E
2C0E ABSIT 2C3C .         2CDE .CCMP      2C44  6        2D4E .SARG     2D78 $
2DA2 .5    2DA6 .2EF0     2DAA .EECNT     2DAC .0        2E02 .MES      2E8C .
2E32 .V    2E0C 01

MON- BLOCKS:
```

```
          IOP=      [illegible].3217
          POT=        .4225
            S=    17.3632
       CITOP=    29.6132
       CIPOT=    29.0368
          TST=  [illegible].323
          TSTS= 2[illegible].329
       STORIT= 29[illegible]    2
          TSP=  2325[illegible].41
          TSS=  2[illegible].41
       SSORIT= 43[illegible].652
```

END

VIO [illegible] SYSTEM VERSION J REVISION 312 08/04/74 GENERATED 04/27/74

```
GR HANDLING CHARGE      =     .35 / JOB          .33
25 LINES PRINTED        =    1.26 / K LINES      .13
84 CARDS READ           =    1.62 / K CARDS      .13
00 PLOTTER VECTORS      =     .25 / 1 K VECTORS  .00
15 MODEL 7 SECONDS      =   25.72 / CPU SEC      .1
00 MODEL 1 SECONDS      =   12.50 / CPU SEC      .00
                        TOTAL CHARGE =          .74
```

[illegible] 14731 LOGGED OUT 04/29/74 18:05. $ 26.17 LEFT AFTER 38 LOGINS.

This case gave a result close to the correct solution with the bottom stressed to almost DST.

Next is presented the "1000 ft steel case" where still another difficulty was encountered and a procedure to have the bottom stressed to DST is exemplified.

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS THE DESIGN STRESS
            DST=25000.
      C     *BM* IS THE BENDING MOMENT
            BM=1.37143*B*DRA*AL*AL
            W=0.30396*(1.-POI*POI)*DST/E
            U=SQRT(W)
            Z=1./U
            *HTOP* IS THE HEAD OF WATER ON DECK
            HTOP=8.
            *HBOT* IS THE  HEAD OF WATER ON BOTTOM
            HBOT=DRA
            STR3T=0.152222*HTOP*Z*Z
            STR3B=0.152222*HBOT*Z*Z
            A=DST-STR3T
            AB=DST-STR3B
            AC=(AB*(B+D)-A*D)/(A*B)
            AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
            AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT=AD/(1.+AC*AE)
            TOP=AC*BOT
            WRITE(5,10)TOP
         10 FORMAT('1',20X,'TOP='F10.4)
            WRITE(5,20)BOT
         20 FORMAT(' ',20X,'BOT='F10.4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=Z*TOP
            WRITE(5,30)S
         30 FORMAT(' ',22X,'S='F10.4)
            P=2.*D*BOT+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*BOT)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*BOT)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
170           GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
1E0     C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
1E0     C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
1E0     C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
1E0     C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
1E0     C     *STCRIT* IS THE CRITICAL STRESS ON TOP
1E0     C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
1E0           TSTH=BM*DITOP/GMI+STR3T
1F4           TSTS=BM*DITOP/GMI+STR3T
208           STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
248           WRITE(5,60)TSTH
264        60 FORMAT(' ',19X,'TSTH='F10.3)
27E           WRITE(5,70)TSTS
29A        70 FORMAT(' ',19X,'TSTS='F10.3)
2B4           WRITE(5,80)STCRIT
2D0        80 FORMAT(' ',17X,'STCRIT='F10.3)
2EC           TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
328           TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
364           SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
3A4           WRITE(5,90)TSBH
3C0        90 FORMAT(' ',19X,'TSBH='F10.3)
3DA           WRITE(5,100)TSBS
3F6       100 FORMAT(' ',19X,'TSBS='F10.3)
410           WRITE(5,110)SBCRIT
42C       110 FORMAT(' ',17X,'SBCRIT='F10.3)
448           END
(S) .U        064C(V) AL        0654(V) B         065C(V) DRA       0664(V) D
(V) POI       0674(V) E         0000(S) .R        0684(V) DST       068C(V) BM
(V) N         06A0(V) U         0000(S) SQRT      06A4(V) Z         06A8(V) HTOP
(V) HBOT      06B4(V) STR3T     06BC(V) STR3B     06C0(V) A         06C4(V) AB
(V) AC        06DC(V) AD        06F0(V) AE        06F8(V) BOT       06FC(V) TOP
(L) 10        0000(S) @I        023A(L) 20        0700(V) S         027C(L) 30
(V) P         0708(V) DITOP     02F8(L) 40        070C(V) DIBOT     0354(L) 50
(V) GMI       071C(V) TSTH      0720(V) TSTS      0724(V) STCRIT    0464(L) 60
(L) 70        04D0(L) 80        0728(V) TSBH      072C(V) TSBS      0730(V) SBCRIT
(L) 90        05F6(L) 100       062C(L) 110       0000(S) .V
 0          L


RAM LABELS:
170 *MAIN*    2E3A .V       2C6A .COMP    298C ALOG     2E48 @I       27A4 .R
232 .ZERO     2C90 $6       27E4 .A       2D8E .MES     2C0C .W       2A94 EXP
29A AINT      2896 SQRT     2CD2 .RARG    2D2E .5       2D04 $8       2D36 .E
336 .0        2E0C .U       3F64


Y-POINTS:
1A4 .R        27E4 .A       2896 SQRT     298C ALOG     2A94 EXP      2B9A AIN
20C .W        2C6A .COMP    2C90 $6       2CD2 .RARG    2D04 $8       2D2E .5
232 .ZERO     2D36 .ERCNT   2D38 .0       2D8E .MES     2E18 .U       2E3E .V
248 @I
```

```
          TOP=     6.1748
          BOT=    -5.5523
            S=   406.7124
        DITOP=   142.0614
        DIBOT=   -70.6328
         TSTH= 24999.992
         TSTS= 24999.992
       STCRIT= 24999.988
         TSBH= 33241.840
         TSBS= 33241.84
       SBCRIT= 2 213.25
ND

 VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74


OB HANDLING CHARGE    $  .35 / JOB          .35
25 LINES PRINTED PR2  $ 1.25 / K LN         .16
54 CARDS READ         $ 1.50 / K CD         .13
70 PLOTTER VECTORS    $  .25 / 1000         .00
21 MODEL 70 SECONDS   $25.00 / HOUR         .15
00 MODEL 80 SECONDS   $12.50 / HOUR         .00
                       TOTAL CHARGE $       .79

RIR 490 14731  LOGGED OUT 04/30/74 21:26.  $  27.07 LEFT AFTER    50 LOGINS.
```

It does not come as a surprise that the program does not work for the "1000 ft steel case" since in this situation we obtain STR3B DST which cannot be accepted and also this program is not prepared to handle.

AL = 1000

B = AL/5.75 = 173.913

DRA = B/3.3 = 52.7

POI = 0.3

$E = 30*10^6$

DST = 25000

$BM = 1.37143*B*DRA*AL^2 = 12569.45*10^6$

$W = 0.30396*(1-POI^2)*DST/E = 230.503*10^{-6}$

$U = W = 15.182*10^{-3}$

Z = 1/U = 65.867

HBOT = DRA = 52.7

$STR3B = 0.152222*HBOT*Z^2 = 34803.57$ DST

Since we understand that the program should work for DST > STR3B we make the next run with DST = 35000 to prove that in such case a solution is obtained, and after proceed to obtain the actual solution for the case we were considering with DST = 25000.

```
C       *AL* IS THE LENGHT
        AL=1000.
        B=AL/5.75
C       *DRA* IS THE DRAFT
        DRA=B/3.3
        D=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *DST* IS THE DESIGN STRESS
        DST=35280.
C       *BM* IS THE BENDING MOMENT
        BM=1.37143*B*DRA*AL*AL
        W=0.30396*(1.-POI*POI)*DST/E
        U=SQRT(W)
        Z=1./U
        *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=8.
        *HBOT* IS THE  HEAD OF WATER ON BOTTOM
        HBOT=DRA
        STR3T=0.152222*HTOP*Z*Z
        STR3B=0.152222*HBOT*Z*Z
        A=DST-STR3T
        AB=DST-STR3B
        AC=(AB*(B+D)-A*D)/(A*B)
        AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
        AE=(3.*B*B+2.*B*D)/ D*D+2.*B*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AD/(1.+AC*AE)
        TOP=AC*BOT
        WRITE(5,10)TOP
   10   FORMAT('1',22X,'TOP='F10.4)
        WRITE(5,20)BOT
   20   FORMAT(' ',22X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
   30   FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*BOT)/P
        WRITE(5,40)DITOP
   40   FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*BOT)/P
        WRITE(5,50)DIBOT
   50   FORMAT(' ',18X,'DIBOT='F10.4)
C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
70          GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
E0     C    *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
E0     C    *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
E0     C    *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
E0     C    *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
E0     C    *STCRIT* IS THE CRITICAL STRESS ON TOP
E0     C    *SBCRIT* IS THE CRITICAL STRESS ON BOT
E0          TSTH=BM*DITOP/GMI+S*R3T
F4          TSTS=BM*DITOP/GMI+S*R3T
08          STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
48          WRITE(5,60)TSTH
64       60 FORMAT(' ',19X,'TSTH='F10.3)
7E          WRITE(5,70)TSTS
9A       70 FORMAT(' ',19X,'TSTS='F10.3)
B4          WRITE(5,80)STCRIT
D0       80 FORMAT(' ',17X,'STCRIT='F10.3)
EC          TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
28          TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
64          SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
A4          WRITE(5,90)TSBH
C0       90 FORMAT(' ',19X,'TSBH='F10.3)
DA          WRITE(5,100)TSBS
F6      100 FORMAT(' ',19X,'TSBS='F10.3)
10          WRITE(5,110)SBCRIT
2C      110 FORMAT(' ',17X,'SBCRIT='F10.3)
48          END
(S] .U      064C[V] AL      0654[V] B       065C[V] DRA     0664[V] D
(V] POI     0674[V] E       0000[S] .R      0684[V] DST     068C[V] BM
S[V] W      06A0[V] U       0000[S] SQRT    06A4[V] Z       06A8[V] HTOP
B[V] HBOT   06B4[V] STR3T   06BC[V] STR3B   06C0[V] A       06C4[V] AB
C[V] AC     06DC[V] AD      06E [V] AE      06F8[V] BOT     06FC[V] TOP
0[L] 10     0000[S] @I      023A[L] 20      0700[V] S       027C[L] 30
([V] P      0708[V] DITOP   02F8[L] 40      070C[V] DIBOT   0354[L] 50
1[V] GMI    071C[V] TSTH    0728[V] TSTS    0724[V] STCRIT  0464[L] 60
9[L] 70     04D0[L] 80      0728[V] TSBH    072C[V] TSBS    0730[V] SBCRIT
C[L] 90     05F6[L] 100     062C[L] 110     0000[S] .V
 J          L


RAM LABELS:
70 *MAIN*   2EBA .V        2CEA .COMP      298C ALOG       2EC8 @I         27A4 .R
B2 .ZERO    2D10 $6        27E4 .A         2E0E .MES       2C8C .W         2A94 EXP
1A AINT     2896 SQRT      2D52 .RARG      2DAE .5         2A94 AEXP       2D86 .E
84 $8       2DB6 .C        2E8C .U         3FE4


Y-POINTS:
A4 .R       27E4 .A        2896 SQRT       298C ALOG       2A94 AEXP       2A94 EXP
1A AINT     2C8C .W        2CEA .COMP      2D10 $6         2D52 .RARG      2D84 $8
AE .5       2DB2 .ZERO     2DB6 .ERCNT     2DB8 .C         2E0E .MES       2E98 .U
BE .V       2EC8 @I
```

```
      TCP=     0.4626
      BCT=     9.7569
        S=    25.7509
    DITCP=    53.9186
    DIBCT=    17.5099
     TSTH= 34999.977
     TSTS= 34999.977
    STCRIT= 3500.016
     TSPH= 1 196.547
     TSPS= 1 196.547
    SBCRIT=********* (TOO HIGH OUTSIDE FORTRAN RANGE)
END

VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED 04/27/74

JOB HANDLING CHARGE    $   .35 / JOB          .35
25 LINES PRINTED FRO $ 1.25 / K LN           .16
84 CARDS READ          $ 1.50 / K CD         .13
00 PLOTTER VECTORS     $   .25 / 10K0        .00
15 MODEL 70 SECONDS    $25.00 / HOUR         .10
00 MODEL 80 SECONDS    $12.50 / HOUR         .00
                        TOTAL CHARGE $       .74

EIR 490 14731  LOGGED OUT 04/29/74 20:46.  $  32.45 LEFT AFTER    43 LOGINS.
```

Now let's consider our situation with DST = 25000. Once the situation is such that due to the approximation made in

$$\frac{S}{BOT} = Z$$

we end up with a STR3B > DST we must consider a value Z1 lower than Z to bring STR3B down. This can be also understood since it is acceptable to make here

$$\frac{S}{TOP} = Z$$

but because we obtain with the program as is TOP $\ll$ BOT, making the approximation

$$\frac{S}{BOT} = Z$$

makes Z attain a much larger value than it actually should. We must then consider Z1 < Z = 65.8 and may start by trying

Z1 = 35

The computer printout in this case is as follows.

```
C       *AL* IS THE LENGHT
        AL=1[illegible].
        B=AL/5.75
C       *D* IS THE DRAFT
        D=AL/3.3
        T=AL/14.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*10.**6
C       *BST* IS THE BENDING STRESS
        BST=[illegible]
C       *BM* IS THE BENDING MOMENT
        BM=1.37143*B*[illegible] AL**4
        W=2.2836*(1.-POI**2)*BST/E
        D=SQRT( )
        Z=1./D
        *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=0.
        *HBOT* IS THE HEAD OF WATER ON BOTTOM
        HBOT=DRA
        STRBT=0.15222*HTOP*Z*Z
        Z1=35.
        STRBF=0.15222*HBOT*Z1*Z1
        A=BST-STRBT
        B=BST-STRBF
        C=(2B*(B+D)-A*T )/(2*B)
        E=B**(B+D)/(2.*D*(D*D+2.*B*T))
        F=(3.*T*B+2.*B*D)/(D*D+2.*B*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=E/(1.+C*AF)
        TOP=C*BOT
        WRITE(5,10)TOP
   10   FORMAT('1',20X,'TOP='F10.4)
        WRITE(5,20)BOT
   20   FORMAT(' ',20X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(5,30)S
   30   FORMAT(' ',20X,'S='F10.4)
        T=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(B*BOT+D*BOT)/P
        WRITE(5,40)DITOP
   40   FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
        DIBOT=D*(B*TOP+D*BOT)/P
        WRITE(5,50)DIBOT
   50   FORMAT(' ',18X,'DIBOT='F10.4)
```

```
  STRENGTH OF SHIPS-ON THE NEUTRAL AXIS LOCATI N                    PAGE   2

178      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
179              GMI=4.*A*D*((D/2.)**2+2.*B*D)*TOP*BOT+(D*D+2.*B*T)*B*T)/P
1A0      C       *ISTH* IS THE STRESS ON TOP DUE TO BOGGING
1B8      C       *ISTS* IS THE STRESS ON TOP DUE TO SAGGING
1C0      C       *TSTH* IS THE STRESS ON BOT DUE TO BOGGING
1C8      C       *TSTS* IS THE STRESS ON BOT DUE TO SAGGING
1D0      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
1D8      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
1E0              ISTH=FM*DITOP/GMI+ST*ST
1E8              ISTS=FMS*DITOP/GMI+STS*ST
1F0              STCRIT=TOP*TCP*F/(1.-.3*396*S*S*(1.-FOI*FOI))
1F8              WRITE(5,62)ISTH
200      62      FORMAT(' ',10X,'ISTH=',F10.3)
208              WRITE(5,70)ISTS
210      70      FORMAT(' ',10X,'ISTS=',F10.3)
218              WRITE(5,80)STCRIT
220      80      FORMAT(' ',10X,'STCRIT=',F10.3)
228              ISTH=FM*DITOP/GMI+.1582222*FBOT*S*/(BOT*BOT)
230              TSTS=FMS*DITOP/GMI+.1582222*FBOT*S*/(BOT*BOT)
238              SBCRIT=BOT*BOT*F/(1.-.3*396*S*S*(1.-FOI*FOI))
240              WRITE(5,92)TSBH
248      90      FORMAT(' ',10X,'TSBH=',F10.3)
250              WRITE(5,100)TSBS
258      100     FORMAT(' ',10X,'TSBS=',F10.3)
260              WRITE(5,110)SBCRIT
268      110     FORMAT(' ',10X,'SBCRIT=',F10.3)
270              END

(5)  .          2654[V] AL      .65C[V] B       0674[V] DRA     0A6C[V] D
(V) BOT         267C[V] E       .700[S] .F      0694[V] DST     06B4[V] FM
(V) .           26A8[V] G       .7??[S] SQRT    06A0[V] Z       06B8[V] FTOP
(V) FBOT        26C0[V] STR3T    6C4[V] Z1      06CC[V] STF3B   06D0[V] Z
(V) AX          26D8[V] AC      6F0[V] AD       0708[V] AE      0720[V] BOT
(V) TOP         2720[L] 10      0000[S] .I      0248[L] 20      0710[V] S
(L) 30          2714[V] P       .718[V] DITOP   0308[L] 40      071C[V] DIBOT
(L) 50          0728[V] GMI     .728[V] TSTH    0730[V] TSTS    0734[V] STCRIT
(L) 60          04A8[L] 70       4D8[L] 80      0738[V] TSBH    073C[V] TSBS
(V) SBCRIT      2BC8[L] 90       5FE[L] 100     0634[L] 110     0040[S] .V
FEQ             L


PROGRAM LABELS:
2270 .MAIN.     2ECA .\         2CFA .COMP      2990 ALOG       2ED8 .I         2784 .F
2LC2 .ZERO      2D24 .G         27F4 .A         2F1E .MES       2C9C .W         2AA4 EX
2C2A ATAN       2B86 SQRT       2A62 .RANG      2DBE .5         2AA4 AEXP       2DC6 .E
2C94 SS         2DC4 .C         2E9C .U         3FF4

KEY-POINTS:
2784 .F         2754 .A         2AA6 SQRT       2990 ALOG       2AA4 AEXP       2AA4 EX
2C2A ATAN       2C9C .W         2CFA .COMP      2D29 .G         2DA2 .RANG      2D94 SS
2BBE .E         2DC2 .ZERO      2DC4 .EPCNT     2DC8 .O         2E1E .YES       2EA8 .U
2ECE .W         2FD6 .1
```

```
      TOP=     3.4224
      EOT=     5.4711
        S=   225.4100
     IITC=    44.3458
     UITT=    31.4423
     TSTM=  24990.0033
     TSTR=  24990.0033
    STCSTT=  24990.0000
     TSCH=  31020.0045
     TSCB=  31020.0045
    SSCHIT=  5489.4211
```

NO

VM/370 OPERATING SYSTEM VERSION 1 REVISION 12 3/04/74 GENERATED 4/27/74

```
CB HANDLING CHARGE      $    .35 / JOB          .35
26 LINES PRINTED PAST   $  1.25 / 1K LN        .14
25 CARDS READ           $  1.25 / 1K CD        .13
00 PLOTTER VECTORS      $    .25 / 100 V        .00
21 MODEL 2  SECONDS     $25.00 / HOUR          .14
04 MODEL 3  SECONDS     $12.00 / HOUR          .01
                        TOTAL CHARGE $         .77
```

USER 400 14731 LOGGED OUT 04/30/74 20:59. $ 31.06 LEFT AFTER 40 LOGINS.

This time we obtained a realistic but still unacceptable result; we notice that the bottom is being stressed to 31000 psi when it can only go up to 25000 psi; besides we assumed

$$Z1 = \frac{S}{BOT} = 35$$

and end up with

$$\frac{S}{BOT} = \frac{225.4}{5.07} = 44.46$$

This means that the Z1 value should be higher.

We may now try Z1 = 40; the computer results for this case are shown next.

STRE GHT OF SHIPS-OF THE NEUTRAL AXIS LOCATION PAGE 1

```
      C       *AL* IS THE LENGHT
              AL=1CC1.
              B=AL/5.75
      C       *DRA* IS THE DRAFT
              DRA=B/3.3
              D=AL/14.
      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C       FOR STEEL
              POI=0.3
      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C       FOR STEEL
              E=3.*E 7.**6
      C       *DST* IS THE DESIGN STRESS
              DST=25 1.
      C       *BM* IS THE BENDING MOMENT
              BM=1.3711*B*DRA*AL*AL
              A=0.3336*(1.-POI*POI)*DST/E
              U=SQRT(A)
              Z=1./U
              *HTOP* IS THE HEAD OF WATER ON DEC-
              HTOP=8.
              *HBOT* IS THE  HEAD OF WATER ON BOTTOM
              HBOT=DRA
              STRST=0.152222*HTOP*Z*Z
              Z1=4.
              STRBR=1.152222*HBOT*Z1*Z1
              A=DST-STRST
              AB=DST-STRBR
              AC=(AB*(3+D)-A*D)/(A*B)
              AD=B**(B+D)/(4.**D*(D+2.*B*D))
              AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
              BOT=AD/(1.+AC*AE)
              TOP=AC*BOT
              WRITE(5,10)TOP
    1 FORMAT('1',20X,'TOP='F12.4)
              WRITE(5,20)BOT
   20 FORMAT(' ',20X,'BOT='F12.4)
      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
              S=Z*TOP
              WRITE(5,30)S
   30 FORMAT(' ',22X,'S='F12.4)
              P=2.*D*BOT+B*(TOP+BOT)
      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
              DITOP=D*(B*BOT+B*BOT)/P
              WRITE(5,40)DITOP
   40 FORMAT(' ',18X,'DITOP='F10.4)
      C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
              DIBOT=D*(B*TOP+B*BOT)/P
              WRITE(5,50)DIBOT
   50 FORMAT(' ',18X,'DIBOT='F10.4)
```

```
27E      C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT Y-A-
27E            GMI=4.*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/3
28E      C      *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
28E      C      *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
29E      C      *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
29E      C      *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
2AE      C      *STOPIT* IS THE CRITICAL STRESS ON TOP
2BE      C      *SBOPIT* IS THE CRITICAL STRESS ON BOT
2CE            TSTH=BM*DITOP/GI+STR3T
2DC            TSTS=-BM*DITOP/GI+STR3T
2E4            STOPIT=TOP*TOP*E/(0.3@396*S*S*(1.-EOI*POI))
2EC            WRITE(5,4C)TSTH
2F6      4C    FORMAT(' ',19X,'TSTH=',F10.3)
2FC            WRITE(5,7C)TSTS
3C2      7C    FORMAT(' ',19X,'TSTS=',F10.3)
3C8            WRITE(5,8C)STOPIT
3D8      8C    FORMAT(' ',17X,'STOPIT=',F10.3)
3E4            TSBH=BM*DIBOT/GI+.1E2222*BBOT*S*E/(BOT*BOT)
3F2            TSBS=BM*DIBOT/GI+.1E2222*BBOT*S*E/(BOT*BOT)
3FC            SBOPIT=BOT*BOT*E/(0.3@396*S*S*(1.-EOI*POI))
4AC            WRITE(5,9C)TSBH
4C8      9C    FORMAT(' ',19X,'TSBH=',F10.3)
4D2            WRITE(5,10C)TSBS
4EE      10C   FORMAT(' ',19X,'TSBS=',F10.3)
4F8            WRITE(5,11C)SBOPIT
534      11C   FORMAT(' ',17X,'SBOPIT=',F10.3)
54C            END
```

[S] ..	0654[V] AL	065C[V] B	0664[V] DRA	066C[V] D			
[V] ..I	067C[V] E	0?0[S] .R	06?C[V] DST	0694[V] BM			
[V] .	06A4[V] '	0?20[S] SQRT	06?C[V] Z	06B?[V] HTOP			
[V] ..OT	06BC[V] STR3T	06C4[V] Z1	06?C[V] STR3B	06D?[V] A			
[V] ..	06D8[V] AC	06EC[V] AD	07 .?[V] AE	0708[V] BOT			
[V] I..	0?2?[L] 1?	0?2?[S] ?I	0?2.?[L] 2?	0710[V] S			
[L] 3.	0714[V] P	0718[V] DITOP	03?[L] 4?	071C[V] DIBOT			
[L] 5.	0720[V] GMI	0728[V] TSTH	07?[V] TSTS	0734[V] STOPIT			
[L] 6.	0742[L] 7?	074?[L] 8?	0753[V] TSBH	073C[V] TSBS			
[V] S..OPIT	05C?[L] 9?	05EE[L] 10?	0604[L] 11?	0000[S] .V			

EC L

PROGRAM LABELS:

2?70 *MAIN*	2ECA .V	2CEA .COMP	299C ALOG	2ED8 @I	2784 .A		
2DC2 .ZERO	2?2C $6	27F4 .A	2E1E .MES	2C9C .W	2A44 E		
2C2A ATAN	2?A6 SQRT	2D62 .PARG	2DBE .5	2AA4 AEXP	2DC6 .E		
2D94 .S	2DC6 .C	2E9C .U	3EF4				

ENTRY-POINTS:

2754 .A	27F4 .A	2?A6 SQRT	299C ALOG	2AA4 AEXP	2AA4 E		
2C2A ATAN	2C9C .W	2CEA .COMP	2D2? $6	2D62 .PARG	2D94 $		
2DBE .5	2DC2 .ZERO	2DC6 .ERCNT	2DC8 .D	2E1E .MES	2EA8 .		
2ECE .V	2ED8 @I						

```
      TOP=     3.2259
      BOT=     6.5253
       S=   199.4554
    CITOP=    44.1743
    CIBOT=    27.2533
     TSTH= 24990.0004
     TSTS= 24990.0004
   STCRIT= 24990.0004
     TSRH= 19514.0034
     TSRS= 19514.0034
   SRCRIT=118337.0001
```

MD

VIO OPERATING SYSTEM VERSION 1 REVISION 012 (3/04/74 GENERATED 4/27/74

```
JOB HANDLING CHARGE      $   .35 / JOB          .35
126 LINES PRINTED PR1    $  1.25 / K LN         .16
 85 CARDS READ           $  1.50 / K CD         .13
 2. PLOTTER VECTORS      $   .35 / 1000.0       .02
 15 MODEL 75 SECONDS     $25.00 / HOUR          .10
 2' MODEL 50 SECONDS     $12.50 / HOUR          .01
                          TOTAL CHARGE $        .74
```

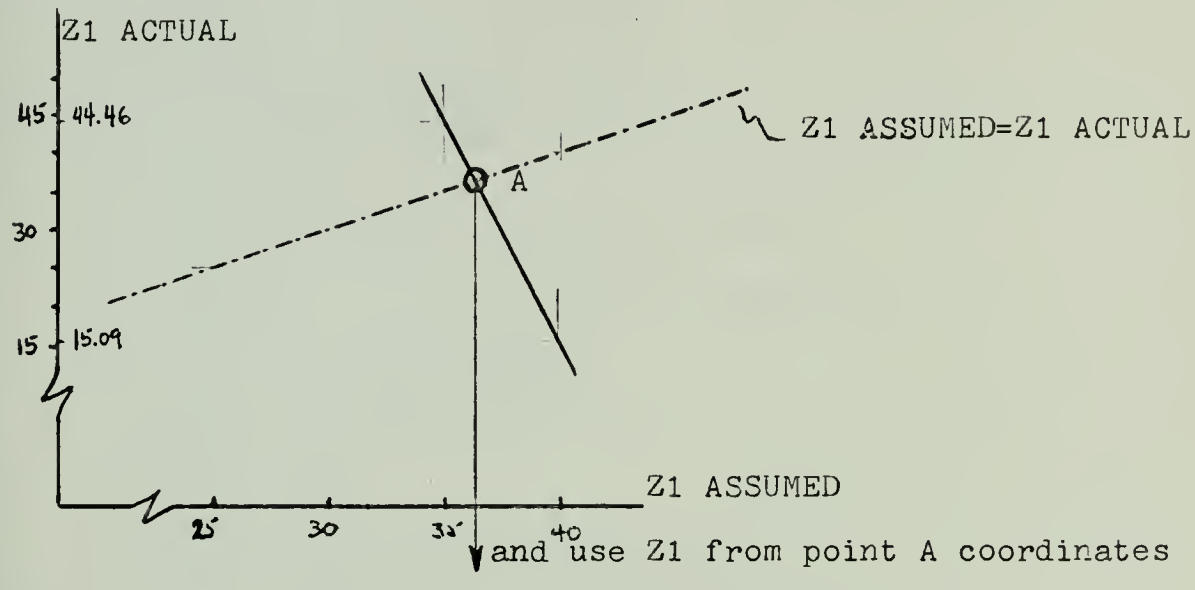
REIR 434 14731 LOGGED OUT 04/29/74 21:22. $ 28.60 LEFT AFTER 28 LOGINS.

In this case we assumed Z1 = 40 and ended up with

$$\frac{S}{BOT} = \frac{199.5}{6.59} = 15.09$$

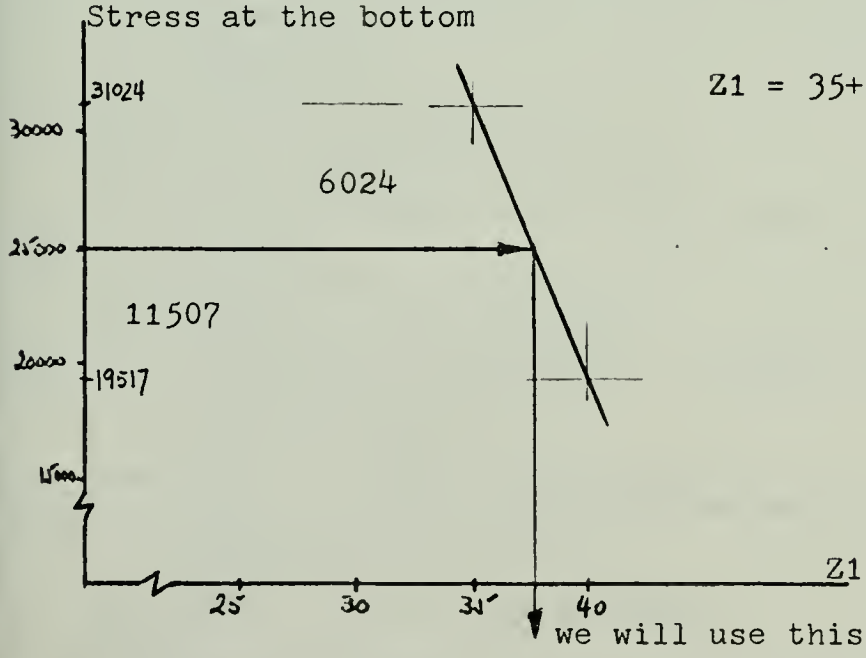
and a stress at the bottom of only 19000 psi which is too small.

We may now try to use a better Z1 value and can do the following:



and use Z1 from point A coordinates

or which is "the same":



$$Z1 = 35 + \frac{5*6024}{11507} = 37.617$$

we will use this Z1 value

The results obtained with this Z1 value are the following:

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
      C     *AL* IS THE LENGHT
            AL=1000.
            B=AL/5.75
      C     *DRA* IS THE DRAFT
            DRA=B/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR STEEL
            POI=0.3
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR STEEL
            E=30.*10.**6
      C     *DST* IS T E DESIGN STRESS
            DST=25000.
      C     *BM* IS THE BENDING MOMENT
            BM=1.37143*B*DRA*AL*AL
            W=0.396*(1.-POI*POI)*DST/E
            U=SQRT(W)
            Z=1./U
            *HTOP* IS THE HEAD OF WATER ON DECK
            HTOP=0.
            *HBOT* IS THE  HEAD OF WATER ON BOTTOM
            HBOT=DRA
            STR3T=0.152222*HTOP*Z*Z
            Z1=35.+5.*SIN(24./115.7.
            STR3B=0.152222*HBOT*Z1*Z1
            A=DST-STR3T
            AB=DST-STR3B
            AC=(AB*(B+D)-A*D)/(A*B)
            AD=BM*(B+D)/(A*4.*D*(D*D+2.*B*D))
            AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT=AD/(1.+AC*AE)
            TOP=AC*BOT
            WRITE(5,10)TOP
         10 FORMAT('1',20X,'TOP='F10.4)
            WRITE(5,20)BOT
         20 FORMAT(' ',20X,'BOT='F10.4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=Z*TOP
            WRITE(5,30)S
         30 FORMAT(' ',22X,'S='F10.4)
            P=2.*D*BOT+B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B+BOT+D*BOT)/P
            WRITE(5,40)DITOP
         40 FORMAT(' ',18X,'DITOP='F10.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B+TOP+D+BOT)/P
            WRITE(5,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT='F10.4)
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
384     C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
384             GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
3F4     C       *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
3F4     C       *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
3F4     C       *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
3F4     C       *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
3F4     C       *STCRIT* IS THE CRITICAL STRESS ON TOP
3F4     C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
3F4             TSTH=BM*DITOP/GMI+STR3T
408             TSTS=BM*DITOP/GMI+STR3T
41C             STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
45C             WRITE(5,60)TSTH
478          60 FORMAT(' ',19X,'TSTH='F10.3)
492             WRITE(5,70)TSTS
4AE          70 FORMAT(' ',19X,'TSTS='F10.3)
4C8             WRITE(5,80)STCRIT
4E4          80 FORMAT(' ',17X,'STCRIT='F10.3)
500             TSBH=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
53C             TSBS=BM*DIBOT/GMI+0.152222*HBOT*S*S/(BOT*BOT)
578             SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
5B8             WRITE(5,90)TSBH
5D4          90 FORMAT(' ',19X,'TSBH='F10.3)
5EE             WRITE(5,100)TSBS
60A         100 FORMAT(' ',19X,'TSBS='F10.3)
624             WRITE(5,110)SBCRIT
640         110 FORMAT(' ',17X,'SBCRIT='F10.3)
65C             END
[S] .U      0660[V] AL      0668[V] B       0670[V] DRA     0678[V] D
[V] POI     0688[V] E       0690[S] .R      0698[V] DST     06A0[V] BM
[V] W       06B4[V] U       06C0[S] SQRT    06B8[V] Z       06BC[V] HTOP
[V] HBOT    06C8[V] STR3T   06D0[V] Z1      06E4[V] STR3B   06F8[V] A
[V] AB      06F0[V] AC      0704[V] AD      0718[V] AE      0720[V] BOT
[V] TOP     0218[L] 10      0728[S] @I      024E[L] 20      0728[V] S
[L] 30      072C[V] P       0738[V] DITOP   030C[L] 40      0734[V] DIBOT
[L] 50      0738[V] GMI     0744[V] TSTH    0748[V] TSTS    074C[V] STCRIT
[L] 60      04AE[L] 70      04E4[L] 80      0750[V] TSBH    0754[V] TSBS
[V] SBCRIT  05D4[L] 90      0604[L] 100     0640[L] 110     2000[S] .V
EQ          L


GRAM LABELS:
070 *MAIN*  2EE2 .V     2D12 .COMP   29B4 ALOG   2EF0 @I     27CC .R
0DA .ZERO   2D38 $6     280C .A      2E36 .MES   2CB4 .W     2A4C EXP
C42 AINT    28BE SQRT   2D7A .RARG   2DD6 .5    2ABC AEXP   2DDE .ER
0AC $8      2DDE .O     2EB4 .U      4000


RY-POINTS:
7CC .R      280C .A     28BE SQRT    2984 ALOG   2ABC AEXP   2AFC EXP
C42 AINT    2CB4 .W     2D12 .COMP   2D38 $6     2D7A .RARG  2D4C $8
0D6 .5      2DDA .ZERO  2DDE .ERCNT  2DE0 .O     2E36 .MES   2EC4 .U
2E6 .V      2EF0 @I
```

```
      TOP=     3.2486
      BOT=     5.7418
        S=   213.9701
    DITOP=    42.2107
    DIBOT=    29.2179
     TSTH= 25000.000
     TSTS= 25000.000
   STCRIT= 24999.992
     TSBH= 24788.316
     TSBS= 24788.316
   SBCRIT= 7?100.937

END

: VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/27/74  1


108 HANDLING CHARGE    $  .35 / JOB          .35
 26 LINES PRINTED PR?  $ 1.25 / K LN         .16
 85 CARDS READ         $ 1.50 / K CD         .13
 00 PLOTTER VECTORS    $  .25 / 1000         .00
 15 MODEL 70 SECONDS   $25.00 / HOUR         .10
 00 MODEL 80 SECONDS   $12.50 / HOUR         .02
                    TOTAL CHARGE $           .74


EIR 490 14731  LOGGED OUT 04/29/74 21:30.  $  27.86 LEFT AFTER     49 LOGINS.
```

The results show that we have obtained

$$Z1 = \frac{S}{BOT} = \frac{213.9701}{5.7418} = 37.265$$

while it was assumed

$$Z1 = 37.617$$

We could further correct the result until Z1 assumed and Z1 actual would coincide but it seems that there is no need to refine more the solution for the purpose here involved.

Note that this procedure should also be followed for the other cases in order to bring the stress at the bottom to its maximum allowed DST for such cases as well.

```
      C     *AL* IS THE LENGHT
            AL=1[illegible].
            B=AL/3.7
      C     *D* IS THE DRAFT
            DA=D/3.3
            D=AL/14.
      C     *POI* IS THE POISSON'S RATIO OF THE MATERIAL
      C     FOR ALUMINUM
            POI=.33
      C     *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
      C     FOR ALUMINUM
            E=10.*10.** 6
      C     *DST* IS THE DESIGN STRESS
            DST=25000.
      C     *BM* IS THE BENDING MOMENT
            BM=1.3714E3*B**2*DA*AL*AL
            W=2.33996*(1.-POI*POI)*DST/E
            T=SQRT(W)
            Z=1./T
            *HTOP* IS THE HEAD OF WATER ON DECK
            HTOP=0.
            *HBOT* IS THE HEAD OF WATER ON BOTTOM
            HBOT=DA
            STRT=1.152E2*HTOP*Z*Z
            STRB=1.152E2*HBOT*Z*Z
            ASST=STRT
            ASB=BOT*STRB
            AC=(ASB*(B+ )+ASA*D)/(2*B)
            AD=BM*(B+D)/(ASA*4.*B*(D*D+2.*B*D))
            AF=(3.*B**2+2.*B*D)/(D*D+2.*B*D)
      C     *TOP* IS THE THICKNESS OF THE TOP PLATING
      C     *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
            BOT=AD/(1.+AC*AF)
            TOP=AC*BOT
            WRITE(6,10)TOP
         10 FORMAT(' ',2X,'TOP=',F17.4)
            WRITE(6,20)BOT
         20 FORMAT(' ',2X,'BOT=',F17.4)
      C     *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
            S=7*TOP
            WRITE(6,32)S
         32 FORMAT(' ',22X,'S=',F13.4)
            P=2.*D*BOT*B*(TOP+BOT)
      C     *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
            DITOP=D*(B*BOT+D*BOT)/P
            WRITE(6,4)DITOP
         40 FORMAT(' ',18X,'DITOP=',F13.4)
      C     *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
            DIBOT=D*(B*TOP+D*BOT)/P
            WRITE(6,50)DIBOT
         50 FORMAT(' ',18X,'DIBOT=',F13.4)
      C     *BMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
```

```
                SMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
C               *TSTH* IS THE STRESS ON TOP DUE TO HOGGING
C               *TSTS* IS THE STRESS ON TOP DUE TO SAGGING
C               *TSBH* IS THE STRESS ON BOT DUE TO HOGGING
C               *TSBS* IS THE STRESS ON BOT DUE TO SAGGING
C               *STCRIT* IS THE CRITICAL STRESS ON TOP
C               *SBCRIT* IS THE CRITICAL STRESS ON BOT
                TSTH=BM*D*.5D/SMI+S-RBT
                TSTS=BM*D*.5D/SMI+S-RBT
                STCRIT=TOP*T**2*E/(1.33396*S*S*(1.-POI*POI))
                WRITE(5,60)TSTH
     60 FORMAT(' ',10X,'TSTH='F17.3)
                WRITE(5,70)TSTS
     70 FORMAT(' ',10X,'TSTS='F17.3)
                WRITE(5,80)STCRIT
     80 FORMAT(' ',10X,'STCRIT='F17.3)
                TBH=BM*D*.5BT/SMI+1.152222*HBOT*S*S/(BOT*BOT)
                TBS=BM*D*.5BT/SMI-1.152222*HBOT*S*S/(BOT*BOT)
                SBCRIT=BOT*BOT*E/(1.33396*S*S*(1.-POI*POI))
                WRITE(5,90)TBSH
     90 FORMAT(' ',10X,'TBSH='F17.3)
                WRITE(5,100)TBSS
    100 FORMAT(' ',10X,'TBSS='F17.3)
                WRITE(5,110)SBCRIT
    110 FORMAT(' ',10X,'SBCRIT='F17.3)
                END
0[S] .U         0440[V] AL      0454[V] B       065C[V] DRA     0664[V] D
0[V] POI        0674[V] E       0678[S] .B      0684[V] DST     0698[V] BM
0[V] H          0690[V] U       06A0[S] SQRT    06A4[V] Z       06A4[V] HTOP
0[V] HBOT       06A8[V] STB3T   06B8[V] STB3B   06BC[V] A       06C0[V] AB
0[V] AC         06D8[V] AD      06E0[V] AE      06E4[V] BOT     06F8[V] TOP
4[L] 14         0[S] SI         0[A][L] 2?      06FC[V] S       227C[L] 32
0[V] P          0734[V] DITOP   725C[L] 42      0778[V] DIBOT   0354[L] 52
0[V] GMI        0718[V] TSTH    0710[V] TSTS    0722[V] STCRIT  0464[L] 62
A[L] 72         0A07[L] 82      0720[V] TSBH    0728[V] TSBS    072C[V] SBCRIT
0[L] 92         5E4[L] 10       0620[L] 112     0020[S] .V
0[V]        L
E
```

EXTERNAL LABELS:

```
0070 *MAIN*     2E56 .V         2C54 .COMP      2988 ALOG       2EC4 $I         27A0 .R
2D4E .ZERO      2770 $A         2752 .A         2E0A .MES       2C88 .W         2A90 EX
2C16 AINT       0A38 SQRT       2D4E .RARG      2DAA .S         2A90 AEXP       2DB2 .E
2D80 $8         2D38 .O         2E2E .U         3FE0
```

ENTRY-POINTS:

```
27A0 .R         2752 .A         2A92 SQRT       2988 ALOG       2A90 AEXP       2A90 EX
2C16 AINT       2C88 .W         2C54 .COMP      2D0C $6         2D4E .RARG      2D80 $8
2D4A .S         2D4E .ZERO      2D10 .EPCNT     2DB4 .O         2E0A .MES       2E94 .U
2E5A .V         2EC4 $I
```

TOT= 2.15
CPU= 0.21
IO= 1.93
DIT P= 0.58
DIT T= 0.42
TSTI= 0.01
TSTO= 0.01
STORE= 0.27
TSH= 1945.727
TSS= 1945.727
ABS ET=1 1982.25

HP

VIC OPERATING SYSTEM VERSION 1 REVISION 312 03/04/74 GENERATED 04/27/74

CPU HANDLING CHARGE	$ .35 / JOB	.35
2E LINES PRINTED 222	$ 1.25 / K LN	.14
44 CARDS READ	.50 / C	.13
23 PLOTTER VECTORS	.25 / 1000	.24
12 MODEL 72 SECONDS	305.33 / HOUR	.12
2% MODEL 82 SECONDS	2.50 / HOUR	.3%
	TOTAL 14895 $	.76

ETR 494 1473 LOGGED OUT 04/27/74 18:28. $ 34.67 LEFT AFTER 40 LOGINS.

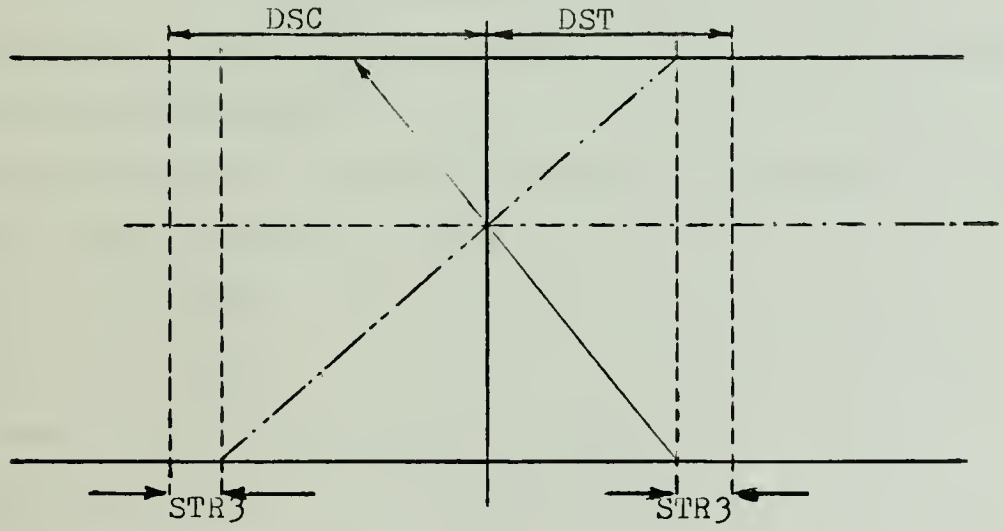
This 1000 ft aluminum case shows again a stress at the bottom much lower than DST. It should be corrected as done for "1000 ft steel" in the previous situation.

HOGGING MOMENT LARGER THAN SAGGING MOMENT

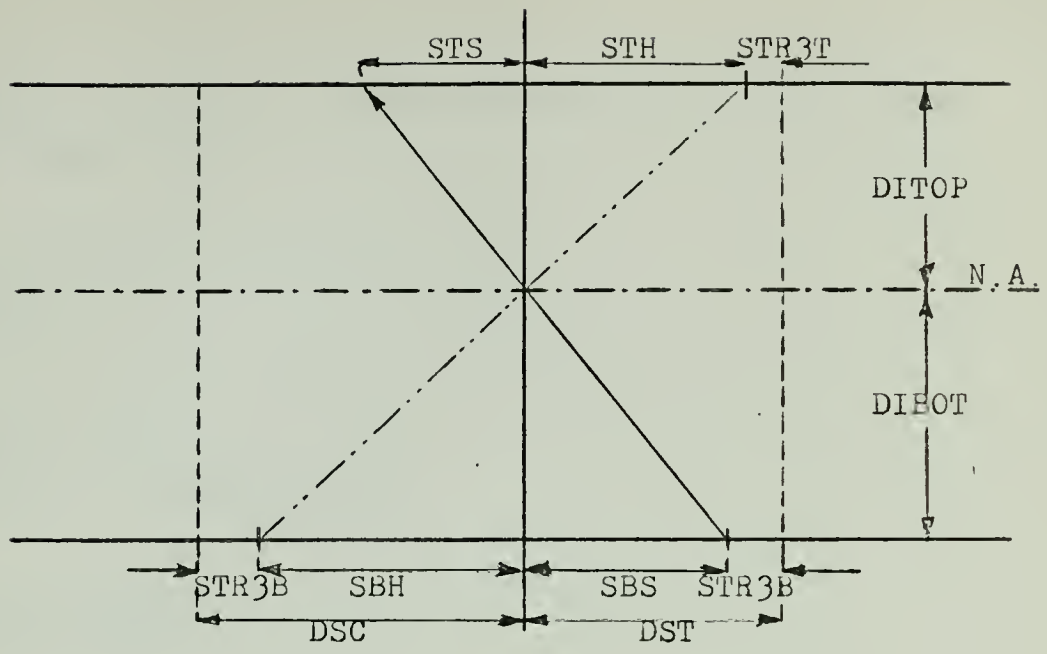
DESIGN STRESS IN COMPRESSION LARGER THAN DESIGN STRESS IN TENSION

LATERAL LOAD ALSO CONSIDERED

With the help of what was understood for the similar situation without the lateral load being included, we may here proceed at once to look at what the diagram of stress distributions might look like. Actually, the diagram that will be considered first is basically the same with only a small change due to the addition of the tertiary stresses; since these will probably be of the same magnitude on both top or bottom and assuming that their actual value does not differ considerably, what we may start looking into is a diagram as follows:



We would consider here the same basic distribution of longitudinal bending stresses thus obtaining



We will then expect to obtain TOP> BOT and DITOP< DIBOT and we may already consider the respective expressions for DITOP, DIBOT and I with TS replaced by TOP

From the diagram we may consider thefollowing equations:

STH*DIBOT=SBH*DITOP

and notice here that if we want to stress the material to the allowable design stresses we have

STH = DST-STR3T

SBH = DSC-STR3B

we may combine these equations to obtain

(DST-STR3T)*DIBOT = (DSC-STR3B)*DITOP

STR3T and STR3B are given by

$$STR3T = 0.152222*HTOP*\left(\frac{S}{TOP}\right)^2$$

$$STR3B = 0.152222*HBOT*\left(\frac{S}{BOT}\right)^2$$

anticipating here that S = Z*BOT because BOT is the thinner plating we have

$$(\frac{S}{BOT})^2 = Z^2$$

and thus may write

$$STR3B = 0.152222*HBOT*Z^2$$

Since

$$(\frac{S}{TOP})^2 < (\frac{S}{BOT})^2$$

because TOP > BOT, if we make

$$(\frac{S}{TOP})^2 = Z^2$$

to simplify the equations that will follow we will understand that in doing so we are only increasing the value of STR3T. This as we see fron

$$STH = DST-STR3T$$

will make us have STH with a slightly lower value than the one that is allowed, so we are on the safe side when we consider

$$(\frac{S}{TOP})^2 = Z^2$$

Now if we end up too much on the safe side and we have a TSTH too low we may bring it to a value closer to DST by considering a Z1 value as done and exemplified in the previous section and done again in this section for the case 1000 ft steel where for this particular exemple it is TSBH that needs correction as explained in detail .

We may then write

$$Z = \frac{1}{\sqrt{0.30396*\frac{1-POI*POI}{E}*DSC}}$$

$$STR3T = 0.152222*HTOP*Z^2$$

$$STR3B = 0.152222*HBOT*Z^2$$

and from

$$(DST-STR3T)*DIBOT = (DSC-STR3B)*DITOP$$

we have if we make

$$A = DST-STR3T$$

$$AB = DSC-STR3B$$

$$P = (2*D+B)*TOP+B*BOT$$

$$A*\frac{D*TOP*(B+D)}{P} = AB*\frac{D*(B*BOT+D*TOP)}{P}$$

which gives after simplification

$$A*((B+D)-AB*D)*TOP = AB*B*BOT$$

and making

$$AC = (A*(B+D)-AB*D)/(AB*B)$$

we have

$$BOT = AC*TOP$$

Following th e suggestions of a previous section we will also use the equation that will make the bottom to be stressed the most in compression under the larger of the moments being considered (HM in this case).

We obtain

$$SBH = HM*DIBOT/I = AB$$

Replacing DIBOT and I by their expressions we obtain

$$AB = \frac{HM*D*TOP*(B+D)}{4*D^2*TOP*((3*B^2+2*B*D)*BOT+(D^2+2*B*D)*TOP)}$$

simplifying we end up with

$$TOP = \frac{HM*(B+D)}{AB*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*BOT$$

now making

$$AD = HM*(B+D)/(AB*4*D*(D^2+2*B*D))$$

$$AE = (3*B^2+2*B*D)/(D^2+2*B*D)$$

we have

$$TOP = AD-AE*BOT$$

substituting here

$$BOT = AC*TOP$$

we obtain finally

$$TOP = \frac{AD}{1+AC*AE}$$

Considering here again the bottom as the location of the thinner plating (in this particular situation we are looking at), and knowing that it will be subject to a compressive stress of magnitude as large as DSC we may again write $S = Z*BOT$
We finally obtain the total stress on top and bottom in both tension and compression by adding the longitudinal bending stresses to the tertiary stresses.

$$TSTH = HM*DITOP/I+0.152222*HTOP*S^2/TOP^2$$

$$TSTS = SM*DITOP/I+0.152222*HTOP*S^2/TOP^2$$

$$TSBH = HM*DIBOT/I+STR3B$$

$$TSBS = SM*DIBOT/I+STR3B$$

NOTE: since usually the secondary stresses are assigned a constant value like 2000 psi or 3000 psi they can be accounted for when giving a value to the design stresses.

```
0004     C      *AL* IS THE LENGHT
0004            AL=500.
000C            R=AL/8.
0018     C      *DRA* IS THE DRAFT
0018            DRA=8/3.
0024            D=AL/9.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR ALU INUM
0030            POI=0.33
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR ALUMINUM
0038            E=10.*1.E**6
004C     C      *DST* IS THE DESIGN STRESS IN TENSION
004C            DST=250.0.
0054     C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054            DSC=300.0.
005C     C      *M* IS THE MAXIMUM BENDING MOMENT
005C            M=1.37143*DISPL*AL
0074     C      *SM* IS THE SECTION BENDING MOMENT
0074            SM=P*DRA*AL
0088            R=0.5*3.1416*(1.-POI)*DSC/E
00A8            U=SQRT(R)
00B4            Z=1./U
00C0            *HTOP* IS THE HEAD OF WATER ON DECK
00C0            HTOP=8.
00C8            *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8            HBOT=DRA
00D0            STR3T=0.15222*HTOP*Z**Z
00E4            STR3B=0.15222*HBOT*Z**Z
00F8            A=DST-STR3T
0104            AB=DSC-STR3B
0110            AC=(A*(1.+D)-AB*T)/(AB*B)
0148            AD=HM*(1.+D)/(AB*4.*D*(T*D+2.*B*D))
0194            AE=(3.*T*B+2.*B**2)/(4.*T*B+2.*B*D)
01E0     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
01E0     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01E0            TOP=AD/(1.+AC*AE)
01F8            BOT=AC*TOP
0204            WRITE(5,10)TOP
0220         10 FORMAT('1',22X,'TOP=',F10.4)
023A            WRITE(5,20)BOT
0256         20 FORMAT(' ',22X,'BOT=',F10.4)
0270     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0270            S=Z*BOT
027C            WRITE(5,30)S
0298         30 FORMAT(' ',22X,'S=',F10.4)
02B0            P=2.*D*TOP+B*(T*D+BOT)
02D4     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02D4            DITOP=D*(2*BOT+3.*TOP)/P
02F8            WRITE(5,40)DITOP
0314         40 FORMAT(' ',18X,'DITOP=',F12.4)
0330     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
   STRENGHT OF SHIPS*ON THE  ROTOR  AXIS LOCATION                    PAGE  2

0330            DIRCT=D*(E*TOP+ *TOP)/F
0354            WRITE(5,65)DIRCT
0370        65  FORMAT(' ',10X,'DIRCT='F10.4)
038C        C   *SMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT  -/-
038C            SMI=4.*(D*(D**2+(D-2.*B)**2)*(D-2.*B)**3*(B+2.*B*E)*TOP*BOT+(D*D+2.*B*E)*TOP**3+BOT
03FC        C   *ISTH* IS THE STRESS (+) TOP DUE TO BOGGING
03FC        C   *ISTS* IS THE STRESS (+) TOP DUE TO SAGGING
03FC        C   *TSBH* IS THE STRESS (-) BOT DUE TO BOGGING
03FC        C   *TSBS* IS THE STRESS (-) BOT DUE TO SAGGING
03FC        C   *SICRIT* IS THE CRITICAL STRESS ON TOP
03FC        C   *SBCRIT* IS THE CRITICAL STRESS ON BOT
03FC            TSTH=WM*CITOP/SMI+.1*2222*HTOP**2*S*S/(TOP*TOP)
0438            TSTS=SM*CITOP/SMI+.1*2222*HTOP**2*S*S/(TOP*TOP)
0474            SICRIT=TOP*1000./(1.3*396*S*S*(1.-POI*POI))
0484            WRITE(5,80)TSTH
04D0        80  FORMAT(' ',10X,'TSTH=',F10.3)
04EA            WRITE(5,70)TSTS
0506        70  FORMAT(' ',10X,'TSTS=',F10.3)
0522            WRITE(5,90)SICRIT
053C        90  FORMAT(' ',10X,'SICRIT='F10.3)
0558            TSBH=WM*CIBOT/SMI+3T*3E
0F6C            TSBS=SM*CIBOT/SMI+3T*3E
0587            SBCRIT=CI*1000./(1.3*396*S*S*(1.-POI*POI))
05C0            WRITE(5,95)TSBH
05DC        95  FORMAT(' ',10X,'TSBH=',F10.3)
05F6            WRITE(5,100)TSBS
0612        100 FORMAT(' ',10X,'TSBS=',F10.3)
062C            WRITE(5,110)SBCRIT
0648        110 FORMAT(' ',10X,'SBCRIT='F10.3)
0664            END

 [S]  •U          1068[V] AL          6A0[V] B          0678[V] DBA       0698 [V] D
B9[V] POI         10B0[V] E           1000[V] •R        06BC[V] DST       16A4[V] DSC
1C[V] HW          1624[V] SM          6A8[V] W          06C4[V] U         1700 [S] SICRIT
C8[V] Z           1CC0[V] HTOP        6D0[V] HBOT       06D4[V] STBOT     06D0[V] STOP
EC[V] A           1EE4[V] AB          16FA[V] AC        06EC[V] AD        2071 [V] AE
14[V] TOP         2718[V] BOT         2200[I] 10        0720[S] @I        2256[L] 2
1C[V] S           2B9A[L] 3C          1730[V] P         0724[V] DITOP     2314[L] 4
28[V] DIBOT       2378[L] 5C          7200[V] SMI       0738[V] TSTH      237C[V] TSTS
34[V] STCRIT      2400[L] 6C          1500[L] 7C        0750[L] 8C        2744[V] TSBH
40[V] TSBS        2740[V] SBCRIT      1500[L] 9C        0612[L] 100       1648[L] 110
 [S] •V
XEQ          L
)F


ROGRAM LABELS:
 2070 *MAIN*    2E56 •V         2C84 •-OMP      2CA8 /LOG       2E64 •I         27C0 •R
 2D4E •7EBO     2CAC •B         2AA2 •A         2CAA •MES       2C28 •U         2A3C EX
 2BB6 AINT      28E2 SQRT       2CEE •BARG      2C4A .5         2D2C •8         2D52 •5
 2D52 •0        2E28 •D         2E30

NTRY-POINTS:
 27C0 •R        2800 •A         2882 SQRT       2AA8 ALOG       2AB4 EXP        2BB6 AI
```

```
          TOP=      1.34 8
          BOT=      [illegible]
            S=     10.27 1
       DITOP=     26.3 33
       DIBOT=     29.2 15
        TSTH= 24459.7 4
        TSTS=  1 1 7.7 1
      STCPIT= 4547 .3 4
        TSPH= 2999 .9 6
        TSBS= 2293 1. 4
      SBCPIT=  3 .  . 39
/ END

OF VIO OPERATING SYSTEM VERSION 1 REVISION   12  3/24/74 GENERATED  4/31/74

 JOB HANDLING CHARGE      $  .25 / JOB          .3
130 LINES PRINTED PR1     $ 1.25 / K LN         .14
 88 CARDS READ            $ 1.5  / K CD         .13
 00 PLOTTER VECTORS       $  .   / 1    .       .
 15 MODEL 7  SECONDS      $25.   / 4    .       .1
 00 MODEL 8  SECONDS      $12.5  / 4    .       .
                          TOTAL CHARGE =        .74

RREIR 490 14731  LOGGED OUT 4/ /74 22:19.  $  26.33 LEFT AFTER    1 LOGINS.
```

As we see the results obtained for the 500 ft aluminum case are acceptable and agree with all our considerations in the derivation of the formulas, namely TOP > BOT.

The following two runs, for 500 ft steel and 1000 ft aluminum show that the results are in disagreement with TOP > BOT used in the formulas. We will see next why this happens and derive the proper set of formulas to be used for such cases.

```
0004     C      *AL* IS THE LENGHT
0004            AL=500.
000C            B=AL/8.
0018     C      *DRA* IS THE DRAFT
0018            DRA=B/3.
0024            D=AL/9.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR STEEL
0030            POI=0.3
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR STEEL
0038            E=30.*10.**6
004C     C      *DST* IS THE DESIGN STRESS IN TENSION
004C            DST=25000.
0054     C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054            DSC=30000.
005C     C      *HM* IS THE HOGGING BENDING MOMENT
005C            HM=1.37143*B*DRA*AL*AL
0074     C      *SM* IS THE SAGGING BENDING MOMENT
0074            SM=B*DRA*AL*AL
0088            V=0.39396*(1.-POI*POI)*DSC/E
00A8            U=SQRT(V)
00B4            Z=1./U
00C0            *HTOP* IS THE HEAD OF WATER ON DECK
00C0            HTOP=0.
00C8            *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8            HBOT=DRA
00D0            STR3T=0.152222*HTOP*Z*Z
00E4            STR3B=0.152222*HBOT*Z*Z
00F8            A=DST-STR3T
0104            AB=DSC-STR3B
0110            AC=(A*(B+D)-AB*D)/(AB*B)
0148            AD=HM*(B+D)/(AB*4.*D*(D*D+2.*B*D))
0194            AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
01E0     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
01E0     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01E0            TOP=AD/(1.+AC*AE)
01F8            BOT=AC*TOP
0204            WRITE(5,10)TOP
0220       10   FORMAT('1',20X,'TOP='F10.4)
023A            WRITE(5,20)BOT
0256       20   FORMAT(' ',20X,'BOT='F10.4)
0270     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0270            S=Z*BOT
027C            WRITE(5,30)S
0298       30   FORMAT(' ',22X,'S='F10.4)
02B0            P=2.*D*TOP+B*(TOP+BOT)
02D4     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02D4            DITOP=D*(B*BOT+D*TOP)/P
02F8            WRITE(5,40)DITOP
0314       40   FORMAT(' ',18X,'DITOP='F10.4)
0330     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
0330            DIBOT=D*(B*TOP+D*TOP)/P
0354            WRITE(5,50)DIBOT
0370         50 FORMAT(' ',18X,'DIBOT='F10.4)
038C      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
038C            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
03FC      C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
03FC      C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
03FC      C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
03FC      C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
03FC      C     *STCRIT* IS THE CRITICAL STRESS ON TOP
03FC      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
03FC            TSTH=HM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
0438            TSTS=SM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
0474            STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
0484            WRITE(5,60)TSTH
04D0         60 FORMAT(' ',19X,'TSTH='F10.3)
04EA            WRITE(5,70)TSTS
0506         70 FORMAT(' ',19X,'TSTS='F10.3)
0520            WRITE(5,80)STCRIT
053C         80 FORMAT(' ',17X,'STCRIT='F10.3)
0558            TSBH=HM*DIBOT/GMI+STR3B
056C            TSBS=SM*DIBOT/GMI+STR3B
05E0            SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
05C0            WRITE(5,90)TSBH
05DC         90 FORMAT(' ',19X,'TSBH='F10.3)
05F6            WRITE(5,100)TSBS
0612        100 FORMAT(' ',19X,'TSBS='F10.3)
062C            WRITE(5,110)SBCRIT
0648        110 FORMAT(' ',17X,'SBCRIT='F10.3)
0664            END
```

```
?[S] .U      0668[V] AL      0674[V] B       0678[V] DRA     068C[V] D
8[V] POI     0690[V] E       0000[S] .R      06A0[V] DST     06A8[V] DSC
0[V] HM      06B8[V] SM      06BC[V] W       06C8[V] U       0004[S] SQRT
C[V] Z       06D0[V] HTOP    06D4[V] HBOT    06D8[V] STR3T   06E0[V] STR3B
4[V] A       06E8[V] AB      06EC[V] AC      0700[V] AD      0714[V] AE
8[V] TOP     071C[V] BOT     0220[L] 10      0000[S] @I      0256[L] 20
0[V] S       0298[L] 30      0724[V] P       0728[V] DITOP   0314[L] 40
C[V] DIBOT   0370[L] 50      0730[V] GMI     073C[V] TSTH    0748[V] TSTS
4[V] STCRIT  04D0[L] 60      05E6[L] 70      053C[L] 80      0748[V] TSBH
C[V] TSBS    0750[V] SBCRIT  05DC[L] 90      0612[L] 100     0648[L] 110
?[S] .V
>EQ          L
F
```

```
OGRAM LABELS:
2870 *MAIN*   2E5A .V       2C8A .COMP    29AC ALOG     2E68 @I       27C4 .R
2D52 .ZERO    2CB0 $6       2804 .A       2DAE .MES     2C2C .W       2AB4 EX
288A AINT     2886 SQRT     2CF2 .RARG    2D4E .5       2D24 $8       2D56 .E
2D56 .O       2E2C .U       3F84

TRY-POINTS:
27C4 .R       2804 .A       2886 SQRT     29AC ALOG     2AB4 EXP      288A AI
```

```
          TOP=     0.3923
          BOT=     0.4748
            S=    28.5459
        DITOP=    29.2419
        DIBOT=    26.3137
         TSTH= 27045.305
         TSTS= 2146.824
       STCRIT= 2483.910
         TSBH= 3000.012
         TSBS= 2490.129
       SBCRIT= 2999.953
END

: VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74

JOB HANDLING CHARGE    $  .35 / JOB          .35
.30 LINES PRINTED PR2  $ 1.25 / K LN         .16
 88 CARDS READ         $ 1.50 / K CD         .13
00 PLOTTER VECTORS     $  .25 / 1 00         .00
:15 MODEL 70 SECONDS   $25.00 / HOUR         .10
00 MODEL 80 SECONDS    $12.50 / HOUR         .00
                        TOTAL CHARGE $       .74

EIR 490 14731  LOGGED OUT 05/01/74 22:23.  $  25.59 LEFT AFTER    02 LOGINS.
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
004     C       *AL* IS THE LENGHT
004             AL=1000.
00C             B=AL/5.75
018     C       *DRA* IS THE DRAFT
018             DRA=B/3.3
024             D=AL/14.
030     C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
030     C       FOR ALUMINUM
030             POI=0.33
038     C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
038     C       FOR ALUMINUM
038             E=10.*12.**6
04C     C       *DST* IS THE DESIGN STRESS IN TENSION
04C             DST=25000.
054     C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
054             DSC=30000.
05C     C       *HM* IS THE HOGGING BENDING MOMENT
05C             HM=1.37143*B*DRA*AL*AL
074     C       *SM* IS THE SAGGING BENDING MOMENT
074             SM=B*DRA*AL*AL
088             W=0.30396*(1.-POI*POI)*DSC/E
0A8             U=SQRT(W)
0B4             Z=1./U
0C0             *HTOP* IS THE HEAD OF WATER ON DECK
0C0             HTOP=8.
0C8             *HBOT* IS THE  HEAD OF WATER ON BOTTOM
0C8             HBOT=DRA
0D0             STR3T=0.152222*HTOP*Z*Z
0E4             STR3B=0.152222*HBOT*Z*Z
0F8             A=DST-STR3T
014             AB=DSC-STR3B
020             AC=(A*(B+D)-AB*D)/(AB*B)
028             AD=HM*(B+D)/(AB*4.**2*(D*D+2.*B*D))
034             AE=(3.*B*B+2.*B*D)/(D*D+2.*B*D)
040     C       *TOP* IS THE THICKNESS OF THE TOP PLATING
040     C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
050             TOP=AD/(1.+AC*AE)
058             BOT=AC*TOP
064             WRITE(5,10)TOP
070         10  FORMAT('1',20X,'TOP='F10.4)
07A             WRITE(5,20)BOT
086         20  FORMAT(' ',20X,'BOT='F10.4)
090     C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0A0             S=Z*BOT
0AC             WRITE(5,30)S
0B8         30  FORMAT(' ',22X,'S='F10.4)
0C0             P=2.*D*TOP+B*(TOP+BOT)
0D4     C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
0D4             DITOP=D*(B*BOT+D*TOP)/P
0E8             WRITE(5,40)DITOP
0F4         40  FORMAT(' ',1?X,'DITOP='F10.4)
100     C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
330           DIBOT=D*(B*TOP+D*TOP)/P
354           WRITE(5,50)DIBOT
370        50 FORMAT(' ',18X,'DIBOT='F10.4)
38C     C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
38C           GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*TOP*TOP)/P
3FC     C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
,FC     C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
3FC     C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
3FC     C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
1FC     C     *STCRIT* IS THE CRITICAL STRESS ON TOP
FC      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
FC            TSTH=HM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
38            TSTS=SM*DITOP/GMI+0.152222*HTOP*S*S/(TOP*TOP)
74            STCRIT=TOP*TOP*E/(0.30396*S*S*(1.-POI*POI))
84            WRITE(5,60)TSTH
D0         60 FORMAT(' ',19X,'TSTH='F10.3)
EA            WRITE(5,70)TSTS
06         70 FORMAT(' ',19X,'TSTS='F10.3)
20            WRITE(5,80)STCRIT
3C         80 FORMAT(' ',17X,'STCRIT='F10.3)
58            TSBH=HM*DIBOT/GMI+STR3B
6C            TSBS=SM*DIBOT/GMI+STR3B
80            SBCRIT=BOT*BOT*E/(0.30396*S*S*(1.-POI*POI))
20            WRITE(5,90)TSBH
DC         90 FORMAT(' ',19X,'TSBH='F10.3)
F6            WRITE(5,100)TSBS
12        100 FORMAT(' ',19X,'TSBS='F10.3)
2C            WRITE(5,110)SBCRIT
08        110 FORMAT(' ',17X,'SBCRIT='F10.3)
04            END
(S) .U        0668(V) AL      0670(V) B       0678(V) DRA     068C(V) D
(V) POI       0690(V) E       0000(S) .R      069C(V) DST     06A4(V) DSC
(V) HM        06B4(V) SM      06BC(V) W       06C4(V) U       0000(S) SQRT
(V) Z         06CC(V) HTOP    06D4(V) HBOT    06D8(V) STR3T   06EC(V) STR3B
(V) A         06E8(V) AB      06EC(V) AC      0700(V) AD      0714(V) AE
(V) TOP       0720(V) BOT     0228(L) 10      0000(S) @I      0256(L) 20
(V) S         0298(L) 30      0728(V) P       072C(V) DITOP   0314(L) 40
(V) DIBOT     037A(L) 50      0734(V) GMI     0740(V) TSTH    0744(V) TSTS
(V) STCRIT    04D0(L) 60      050A(L) 70      053C(L) 80      074C(V) TSBH
(V) TSBS      0754(V) SBCRIT  05DC(L) 90      0612(L) 100     0648(L) 110
(S) .V
0             L


RAM LABELS:
170 *MAIN*    2E5E .V         2CFE .COMP      29B0 ALOG       2E6C @I         27C8 .R
256 .ZERO     2CB4 $6         2808 .A         2DB2 .MES       2C30 .W         2AB8 EXP
BE AINT       28BA SQRT       2CF6 .RAFG      2D52 .5         2D28 $8         2D5A .ERO
05A .O        2E30 .U         3F88


RY-POINTS:
2C8 .R        2808 .A         28BA SQRT       29B0 ALOG       2AB8 EXP        28BE AINT
```

```
          TOP=     3.1023
          BOT=     3.8359
            S=   134.5649
        DITOP=    38.4762
        DIBOT=    32.9524
         TSTH= 25792.578
         TSTS= 19427.625
       STCRIT= 19622.289
         TSBH= 29999.980
         TSBS= 24548.805
       SBCRIT= 30000.031
END

: VIO OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  04/30/74  1

JOB HANDLING CHARGE    $  .35 / JOB          .35
30 LINES PRINTED PR2   $ 1.25 / K LN         .16
88 CARDS READ          $ 1.50 / K CD         .13
00 PLOTTER VECTORS     $  .25 / 1000         .00
22 MODEL 70 SECONDS    $25.00 / HOUR         .15
00 MODEL 80 SECONDS    $12.50 / HOUR         .00
                     TOTAL CHARGE $          .79

EIR 490 14731  LOGGED OUT 25/01/74 22:26.  $  24.80 LEFT AFTER    03 LOGINS.
```

STEEL

POI = 0.3

$E = 30*10^6$

AL = 500

B = AL/8 = 62.5

DRA = B/3 = 20.833

D = AL/9=55.556

$HM = 1.37143*B*DRA*AL^2 = 44642.187*10^4$

$SM = B*DRA*AL^2 = 32551.562*10^4$

$W = 0.30396*(1-POI^2)*DSC/E = 276.6*10^{-6}$

Z = 60.129

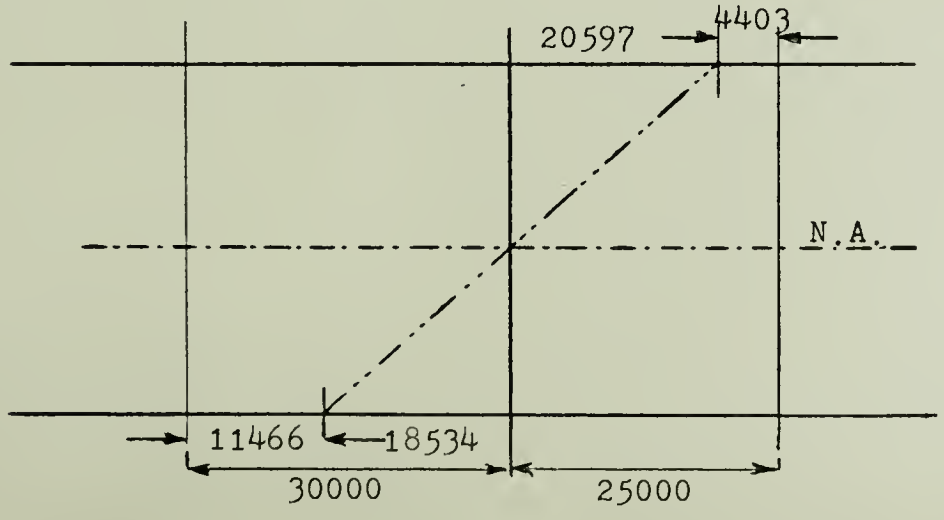
HTOP = 8

HBOT = 20.833

$STR3T = 0.152222*HTOP*Z^2 = 4402.865$ note that this value should be corrected for the Z approximation and actually is slightly smaller

$STR3B = 0.152222*HBOT*Z^2 = 11465.61$

We see from the tertiary stresses obtained that we end up with the following diagram of stress distributions:



From the diagram we see that theneutral axis will end up closer to the bottom and so we must consider BOT > TOP in the formulas.

The same type of diagram will be obtained for 1000'aluminum case since the tertiary stresses obtained in such case are

STR3T = 1498.73

STR3B = 9873.078

For the 1000' steel case the same type of diagram will occur due to the tertiary stresses being

STR3T = 4402.86

STR3B = 29004.

Besides this situation requiring us also to consider the neutral axis closer to the bottom, still another problem arises since STR3B is larger than DST=25000. This case is solved by properly correcting the inaccuracy that was introduced by the Z approximation as exemplified next.

Now let's derive the formulas capable of handling the 500' steel case, the 1000' steel case and the 1000' aluminum case.

We must consider BOT > TOP and DITOP > DIBOT

DITOP = D*(B+D)*BOT/P

DIBOT = D*(B*TOP+D*BOT)/P

$I = 4*D^2*BOT*((3*B^2+2*B*D)*TOP+(D^2+2*B*D)*BOT)/P$

where

P = 2*D*BOT+B*(TOP+BOT)

Starting again with the equation

STH*DIBOT = SBH*DITOP

and making

A = DST-STR3T

AB = DSC-STR3B

we obtain

A*DIBOT = AB*DITOP

Knowing that now the top is the thinner plating we anticipate

S = Z*TOP

and may write

$STR3T = 0.152222*HTOP*Z^2$

$STR3B = 0.152222*HBOT*Z^2$

where the Z value in STR3B should be $\frac{S}{BOT}$ which has a smaller value than Z.

We then obtain:

A*D*(B*TOP+D*BOT)/P = AB*D*(B+D)*BOT/P

Simplifying and making

$$AC = (AB*(B+D)-A*D)/(A*B)$$

we obtain

$$TOP = AC*BOT$$

Making now the top to be stressed the most in tension we have.

$$STH = HM*DITOP/I = A$$

Replacing DITOP and I by their equations we have

$$A = \frac{HM*D*(B+D)*BOT}{4*D^2*BOT*((3*B^b+2*B*D)*TOP+(D^2+2*B*D)*BOT)}$$

and obtain

$$BOT = \frac{HM*(B+D)}{A*4*D*(D^2+2*B*D)} - \frac{3*B^2+2*B*D}{D^2+2*B*D}*TOP$$

Making

$$AD = HM*(B+D)/(A*4*D*(D^2+2*B*D))$$

$$AE = (3*B^2+2*B*D)/(D^2+2*B*D)$$

the formulas become

$$BOT = AD-AE*TOP$$

and substituting

$$TOP = AC*BOT$$

we finally have

$$BOT = \frac{AD}{1+AC*AE}$$

The results obtained for the examples chosen are presented next:

```
C       *AL* IS THE LENGHT
        AL=6200.
        B=AL/20.
C       *D* IS THE DRAFT
        D=B/3.
        D=21/9.
C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
C       FOR STEEL
        POI=0.3
C       *E* IS THE YOUNGIS MODULUS OF THE MATERIAL
C       FOR STEEL
        E=30.*1.**6
C       *DST* IS THE DESIGN STRESS IN TENSION
        DST=25000.
C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
        DSC=30000.
C       *BM* IS THE MAXIMUM BENDING MOMENT
        BM=1.37142*B**2*D*AL*AL
C       *BS* IS THE MAXIMUM BENDING MOMENT
        BS=.1*B**2*D*AL*AL
        A=1.333333*(1.+POI+POI)*DSC/E
        CALL SQRT(A)
        Z=1./A
C       *HTOP* IS THE HEAD OF WATER ON DECK
        HTOP=8.
C       *HBOT* IS THE HEAD OF WATER ON BOTTOM
        HBOT=[illegible]
        STRBT= .15222**2*HTOP*Z*Z
        STRBB= .15222**2*HBOT*Z*Z
        A=BST-STRBT
        AB=DSC-STRBB
        AC=(AB*(B+D)-A*C)/(A*D)
        AD=BM*(C+D)/(A*4.*C*(C*D+2.*B*D))
        AE=(3.*C*B+2.*B**2)/(L*L+2.*S*D)
C       *TOP* IS THE THICKNESS OF THE TOP PLATING
C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
        BOT=AD/(1.+AC*AE)
        TOP=AC*BOT
        WRITE(6,10)TOP
   10   FORMAT('1',22X,'TOP='F10.4)
        WRITE(6,20)BOT
   20   FORMAT(' ',22X,'BOT='F10.4)
C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
        S=Z*TOP
        WRITE(6,30)S
   30   FORMAT(' ',22X,'S='F10.4)
        P=2.*D*BOT+B*(TOP+BOT)
C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
        DITOP=D*(P*BOT+C*BOT)/P
        WRITE(6,40)DITOP
   40   FORMAT(' ',18X,'DITOP='F10.4)
C       *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

```
 STRENGHT  F SHIPS-ON THE  OUTEAL AXIS LOCATIO N                    PAGE    2

330             TOPI=  *(2*TOP+ *BOT)/P
354              RITE(5,52)TIBOT
37C         52  F  MAT(' ',18X,'TIBOTI='F10.4)
38C     C       *  I* IS THE MO ENT O- INERTIA OF THE Y SECTION ABOUT  *A*
38C             GMI=*.*L*C*((2.*  **+2.*D*D)*TOP*BOT+(D*D+2.*B*T)*BOT*B  T)/P
3EC     C       *TSTH*IS THE ST SS  ,  TOP DUE TO  OGGING
3EC     C       *TSTS*IS THE ST SS  ,  TOP DUE TO  AGGING
3EC     C       *TSH *IS THE ST SS  ,  BOT DUE TO  OGGING
3EC     C       *TS  *IS THE ST SS  ,  BOT DUE TO  AGGING
3EC     C       *STCRIT* IS THE CRITICAL STRESS ON TOP
3EC     C       *S CRIT* IS THE CRITICAL STRESS ON BOT
3EC             TSTH=H  *TITOP/G  I+ST  AT
410             I  TS=S  *  TITOP/G  I+ST  AT
424             STCRIT=ITOP*TOP*L/(  .3*3E6*S*S*(1.-POI*POI))
464              RITE(5,62)TSTH
48C         62  F  MAT(' ',19X,'TSTH=',F10.3)
49A              RITE(5,72)TSTS
4B6         72  F  MAT(' ',19X,'TSTS=',F10.3)
4D4              RITE(5,82)STCRIT
4EC         82  F  MAT(' ',17X,'STCRIT='F10.3)
528             TSH=H *TIBOT/G  I+ .1*2222*HBOT*S*S/(BOT*BOT)
544             TS=S *TIBOT/G  I+ .1*2222*HBOT*S*S/(BOT*BOT)
580             SCRIT= (T*TOT*  /(  .3*3E6*S*S*(1.-POI*POI))
5C4              RITE(5,92)TSBH
5DC         92  F  MAT(' ',19X,'TSBH=',F10.3)
5FA              RITE(5,102)TSBS
 12         102 F  MAT(' ',19X,'TSBS=',F10.3)
 32C             RITE(5,112)SBCRIT
 34F        112 F  MAT(' ',17X,'SBCRIT='F10.3)
 364             END

 [S] .U          0A8[V] AL       0672[V] B       0678[V] DRA     0680[V] D
 [V] POI         0698[V] E       0694[V] .K      06A0[V] DST     06A8[V] DTC
 [V] HW          06B8[V] SW      06BC[V] W       06C8[V] U       06D0[S] SQRT
 [V] Z           06DC[V] HTOP    06E4[V] HBOT    06E8[V] STR3T   06EC[V] STR3B
 [V] A           06F8[V] AB      06FC[V] AC      0710[V] AD      0714[V] AE
 [V] BOT         071C[V] TOP     0722[L] 10      0730[S] @I      0750[L] 20
 [V] S           0798[L] 30      0724[V] P       0728[V] DITOP   0814[L] 40
 [V] DIBOT       0870[L] 50      0730[V] GMI     073C[V] TSTH    0740[V] TSTS
 [V] STCRIT      0848[L] 60      0748[L] 70      084C[L] 80      0748[V] TSBH
 [V] TSBS        0750[V] SBCRIT  0850[L] 90      0612[L] 100     0648[L] 110
 [S] .V
 END          L


PROGRAM LABELS:
0270 *MAI**     02EA .V         02DA .COMP      29AC ALOG       02EE @I         27C4 .R
00D2 .7EPO      0203 $6         2*04 .A         2E2E .MES       2CAC .W         2AB4 EX
03A AINT        0216 SQRT       2072 .SARG      20CE .5         2AB4 AEXP       20D6 .E
0A4 $9          0216 .C         2EAC .U         4*04

ENTRY-POINTS:
27C4 .R         2804 .A         2886 SQRT       29AC ALOG       2AB4 AEXP       2AB4 EX
```

```
      IOP=      [illegible]
      NOT=      [illegible]
        S=     22.3[illegible]
    DIIOP=     29.241[illegible]
    DINOT=     26.313[illegible]
      TST=  [illegible]
      TSTS=  19421.[illegible]
    STCHIT=  [illegible]
      ISPH=  26[illegible]
      ISCS=  21[illegible]
    SHCHIT=  45627.742
```

[illegible]

[illegible] VIO OPERATING SYSTEM VERSION [illegible] REVISION [illegible]12 03/04/74 GENERATED 5/02/74

```
[illegible] HANDLING [illegible]      @   .35 / [illegible]        .3[illegible]
[illegible] LINES [illegible]         @  1.25 / K L        .1[illegible]
[illegible] CARDS [illegible]         @  1.50 / [illegible]        .1[illegible]
[illegible] PLOTTER [illegible]       @   .25 / 1[illegible]       .0[illegible]
21 MODEL 7[illegible]              $25.[illegible]                 .1
[illegible] MODEL 8[illegible]     $12.[illegible]                 .[illegible]
                                TOTAL CHA[illegible]               .7[illegible]
```

[illegible]EIR 49 14731 LOGGED OUT 29/09/7[illegible] 12:41. $ 17.92 LEFT AFTER 12 LOGINS.

We could have obtained TSBH = 30000 by correcting the approximation used Z = S/BOT as is done for the 1000' steel case that follows next.

In this case we already anticipate the use of a Z1 value as done in the previous section and according to the output obtained we will then obtain the correct result.

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 1

```
004     C       *AL* IS THE LENGHT
004             AL=100.
00C             B=AL/5.75
018     C       *DRA* IS THE DRAFT
018             DRA=B/3.3
024             E=AL/14.
030     C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
030     C       FOR STEEL
030             POI=0.3
038     C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
038     C       FOR STEEL
038             E=30.*10.**6
040     C       *DST* IS THE DESIGN STRESS IN TENSION
040             DST=24.0
054     C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
054             DSC=22.0
06C     C       *BM* IS THE HOGGING BENDING MOMENT
06C             BM=1.2/143.*B*DRA*AL*AL
074             *BM* IS THE SAGGING BENDING MOMENT
076             SM=0.9*B*B*AL*AL
0A8             W=0.3*B**2*(1.-POI*POI)*DSC/E
0A8             D=SQRT(W)
0B6             Z=1./D
0C0             *HTOP* IS THE HEAD OF WATER ON DECK
0C0             HTOP=0.
0C8             *HBOT* IS THE HEAD OF WATER ON BOTTOM
0CC             HBOT=D*A
0D2             STBOT= .152222*HTOP*Z*Z
0E4             Z1=35.
0E0             STBOT= .152222*HBOT*Z1*Z1
100             A=DST-STBOT
102             A1=DSC-STBOT
110             TC=(A**(3+D)*A*D)/(A*B)
118             TC=(A**(2+D)/(A*4.**D*(D*D+2.**B*D))
120             TB=(3.**B*B+2.**B*D)/(D*D+2.*B*D)
12E     C       *TOP* IS THE THICKNESS OF THE TOP PLATING
134     C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
13E             BOT=AC/(1.+AC*AE)
142             TOP=10.*BOT
146             WRITE(5,10)TOP
152         10  FORMAT(' ',2X,'TOP='F10.4)
15A             WRITE(6,20)BOT
166         20  FORMAT(' ',2X,'BOT='F10.4)
16E     C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
16E             S=2.*TOP
174             WRITE(6,30)S
17A         30  FORMAT(' ',2X,'S='F10.4)
182             P=2.*(B+B)*BOT+B*(TOP+BOT)
18C     C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
18C             DITOP=D*(B*BOT+D*BOT)/P
194             WRITE(6,40)DITOP
19C         40  FORMAT(' ',1X,'DITOP='F10.4)
```

```
0333      C      'DIRCT' IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0333             IBOT=D*(B+TOP+3.*BOT)/P
035C             WRITE(5,5)IBOT
0379          50 FORMAT(' ',19X,'DIA T='F10.4)
0394      C      'GMI' IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
03C4             GMI=4.*(B*D**3.+B*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
0414      C      'TSTH' IS THE STRESS ON TOP DUE TO HOGGING
0424      C      'TSTS' IS THE STRESS ON TOP DUE TO SAGGING
0434      C      'TSBH' IS THE STRESS ON BOT DUE TO HOGGING
0444      C      'TSBS' IS THE STRESS ON BOT DUE TO SAGGING
0454      C      'STCRIT' IS THE CRITICAL STRESS ON TOP
0464      C      'SBCRIT' IS THE CRITICAL STRESS ON BOT
0474             TSTH=HM*BOT/GMI+S*BOT
0518             TSTS=SM*BOT/GMI+STBOT
057C             STCRIT=TOP*TOP*E/(1.3*396*S*S*(1.+POI*POI))
05AC             WRITE(5,6)TSTH
05D8          60 FORMAT(' ',19X,'TSTH='F10.3)
05E8             WRITE(5,7)TSTS
0610          70 FORMAT(' ',19X,'TSTS='F10.3)
0628             WRITE(5,8)STCRIT
0654          80 FORMAT(' ',17X,'STCRIT='F10.3)
0670             TSBH=HM*BOT/GMI+.15222*HBOT*S*S/(BOT*BOT)
06C0             TSBS=SM*BOT/GMI+.15222*HBOT*S*S/(BOT*BOT)
0708             SBCRIT=BOT*BOT*E/(1.3*396*S*S*(1.+POI*POI))
0758             WRITE(5,9)TSBH
0764          90 FORMAT(' ',19X,'TSBH='F10.3)
0780             WRITE(5,10)TSBS
079A         100 FORMAT(' ',19X,'TSBS='F10.3)
07B4             WRITE(5,11)SBCRIT
07D0         110 FORMAT(' ',17X,'SBCRIT='F10.3)
07EC             END
```

```
.U        07E0[V] AL       07F8[V] B        0880[V] DRA      0888[V] D
POI       0898[V] E        0900[S] .5       08A8[V] DST      08B0[V] DSC
HM        08C0[V] SM       08C4[V] W        08D0[V] U        0900[S] SQRT
Z         08D8[V] HTOP     08E0[V] HBOT     08E4[V] STRBT    08EC[V] Z1
STRBT     08F8[V] A        08FC[V] AB       0900[V] AC       0914[V] AD
AE        0930[V] BOT      0934[V] TOP      0228[L] 10       0000[S] @I
20[L]     0938[V] S        02A0[L] 30       093C[V] P        0944[V] DITOP
40[L]     0944[V] DIBOT    0378[L] 50       0948[V] GMI      0954[V] TSTH
TSTS      095C[V] STCRIT   04B8[L] 60       04BE[L] 70       04F4[L] 80
TSBH      0964[V] TSBS     0968[V] SBCRIT   05E4[L] 90       061A[L] 100
110[L]    0900[S] .V
YES          L
OF
```

PROGRAM LABELS:

```
2070 *MAIN*    2EF2 .V        2D22 .COMP     29C4 ALOG      2F00 @I        27DC .
2DEA .ZERO     2D48 $6        2810 .A        2E46 .YES      2CC4 .W        2ACC E
2C52 AINT      28CE SQRT      2D9A .RARG     2DE6 .5        2ACC AEXP      2DEE .
2DBC $8        2DEE .C        2EC4 .U        421C
```

ENTRY-POINTS:

```
      TCP=     3.5788
      BCT=     3.6864
        S=   215.1808
   DITCP=    36.1863
   DIBCT=    35.3423
    TSTH= 21620.000
    TSTS=  1421.525
  STCRIT=  2909.984
    TSPH=  7512.793
    TSPS=  449.328
  SBCRIT=  1824.254
EOD

OF VTL OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/02/74

JOB HANDLING CHARGE          @   .35 / JOB          .35
131 LINES PRINTED 882        @  1.25 / K LN         .16
 69 CARDS READ               @  1.50 / K CD         .13
 00 PLOTTER VECTORS          @   .25 / 1000         .00
 15 CODEL 78 SECONDS         @ 225.00 / HOUR         .10
 00 CODEL 00 SECONDS         @ 312.50 / HOUR         .00
                          TOTAL CHARGE @            .74

OPEIM 497 14731  LOGGED OUT 79/12/75 02:48.  $  16.44 LEFT AFTER    14 LOGINS
```

```
0004      C       *AL* IS THE LENGHT
0004              AL=1[illegible]2.
000C              B=AL/5.75
0018      C       *DRA* IS THE DRAFT
0018              DRA=B/3.2
0024              D=AL/14.
0030      C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030      C       FOR STEEL
0030              POI=[illegible].3
0038      C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038      C       FOR STEEL
0038              E=30.*1[illegible].**6
004C      C       *DST* IS THE DESIGN STRESS IN TENSION
004C              DST=25.[illegible].
0054      C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054              DSC=30[illegible].
005C      C       *BM* IS THE HOGGING BENDING MOMENT
005C              BM=1.37*.83*B**2*AL*AL
0074      C       *SM* IS THE SAGGING BENDING MOMENT
0074              SM=B*D**2*AL*.1
0088              W=[illegible].3**4*(1.-POI*POI)*DSC/E
00A8              U=SQRT([illegible])
00B4              Z=1./U
00C0              *HTOP* IS THE HEAD OF WATER ON DEC
00C0              HTOP=5.
00C8              *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8              HBOT=DRA
00D0              STRST= .152222*HTOP*Z**2
00E4              Z1=4[illegible].
00EC              STRSB= .152222*HBOT*Z1*Z1
0100              A=DST-STRST
010C              AB=DSC+STRSB
0118              AC=(AB*(3.+D)+A*)/(A*B)
0150              AD=H*(3.+D)/(A*3.**2)*(5.*D+2.*B*D))
019C              AE=(3.* .+2.*B*D)/(5.*D+2.*B*D)
01E8      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
01E8      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01E8              BOT=AD/(1.+AC*AE)
0200              TOP=AC*BOT
020C              WRITE(5,10)TOP
0228          1   FORMAT('1',2[illegible]X,'TOP='F10.4)
0242              WRITE(5,22)BOT
025E          2   FORMAT(' ',2[illegible]X,'BOT='F1[illegible].4)
0278      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0278              S=Z*TOP
0284              WRITE(5,3[illegible])S
0290          3   FORMAT(' ',22X,'S='F10.4)
02B8              B=2.*D*BOT+B*(TOP+BOT)
02DC      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02DC              DITOP=D*(B*BOT+D*BOT)/B
0300              WRITE(5,4[illegible])DITOP
031C          4   FORMAT(' ',1[illegible]X,'DITOP='F10.4)
```

```
   STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION                    PAGE    2

0338     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0338            DIBOT=D*(2.*TOP+3.*BOT)/P
035C            WRITE(5,6)DIBOT
0378        6   FORMAT(' ',13X,' IBOT='F10.4)
0394     C      *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT *A*
0394            GMI=4.*((2.*B*D**3+(D-2.*B)*TOP*BOT*(D+2.*B-C)**2)/12.)
0404     C      *ISTH* IS THE STRESS ON TOP DUE TO HOGGING
0404     C      *ISTS* IS THE STRESS ON TOP DUE TO SAGGING
0404     C      *ISBH* IS THE STRESS ON BOT DUE TO HOGGING
0404     C      *ISBS* IS THE STRESS ON BOT DUE TO SAGGING
0404     C      *STCRIT* IS THE CRITICAL STRESS ON TOP
0404     C      *SBCRIT* IS THE CRITICAL STRESS ON BOT
0404            ISTH=HM*(D-TOP/3.)*TOP/GMI+STBOT
0418            ISTS=SM*(D-TOP/3.)*TOP/GMI+STBOT
042C            STCRIT=TOP*TOP*F/(1.-.396*S*S*(1.-POI*POI))
046C            WRITE(5,7)ISTH
0488        7   FORMAT(' ',19X,'ISTH='F10.3)
04A2            WRITE(5,8)ISTS
04BE        8   FORMAT(' ',19X,'ISTS='F10.3)
04DE            WRITE(5,9)STCRIT
04F4        9   FORMAT(' ',17X,'STCRIT='F10.3)
0510            ISBH=HM*(BOT/GMI+.166222*HBOT*S*S/(BOT*BOT)
054C            ISBS=SM*(BOT/GMI+.166222*HBOT*S*S/(BOT*BOT)
0588            SBCRIT=BOT*BOT*F/(1.-.396*S*S*(1.-POI*POI))
05C8            WRITE(5,10)ISBH
05E4       10   FORMAT(' ',19X,'ISBH='F10.3)
05FE            WRITE(5,11)ISBS
061A       11   FORMAT(' ',19X,'ISBS='F10.3)
0634            WRITE(5,12)SBCRIT
0650       12   FORMAT(' ',17X,'SBCRIT='F10.3)
066C            END

0 [S] .0        0670 [V] AL         0728 [V] A          0760 [V] DRA        0798 [V] D
90 [V] POI      0698 [V] E          06C0 [S] .R         06E8 [V] IST        0700 [V] STC
B8 [V] HM       06C8 [V] SM         0724 [V] I          0740 [V] U          0758 [S] SCRT
D4 [V] Z        06D8 [V] HTOP       0750 [V] HBOT       0764 [V] STBT       0780 [V] Z1
F4 [V] STB3     06F8 [V] A          0770 [V] AB         0790 [V] AC         07B4 [V] AD
20 [V] AE       0730 [V] BOT        0738 [V] TOP        0748 [L] 10         0760 [S] 81
5E [L] 20       0738 [V] S          0780 [L] 30         0790 [V] P          07A4 [V] DITOP
1C [L] 40       0744 [V] DIBOT      07B0 [L] 50         07C8 [V] GMI        07D4 [V] ISTH
58 [V] ISTS     075C [V] SICRIT     07E8 [L] 60         07F4 [L] 70         0804 [L] 80
68 [V] ISBH     0764 [V] ISBS       0800 [L] 90         0814 [L] A0         0828 [L] B0
C0 [L] 110      0840 [S] .V
>XEQ            L
0F


PROGRAM LABELS:
 2070 *MAIN*    2EF2 .V         2F22 .COMP      2FC4 ALOG       2F00 BT         2FDC .S
 2DEA .ZERO     2D4A SE         2E1C .A         2E46 .MES       2CC4 .V         2ACC EX
 2C52 AINT      2ACE SQRT       2F8A .SARG      2FE6 .5         2ACC AEXP       2DEE .T
 2D8C $8        2DEE .C         2EC4 .U         4C1C

ENTRY-POINTS:
 27DC .R        281C .A         2ACE SQRT       2AC4 ALOG       2ACC AEXP       2ACC EX
```

```
                TCP=     3.3 66
                BOT=     4.4277
                  S=   203.62-3
             DITCP=    39.9611
             DIBOT=    32.4574
               TSTM=  2[illegible].
               TSTS=  1[illegible]
            STCMIT=  2[illegible]
               TSRM=  34131.-55
               TSRS=  2[illegible]
            SRCMIT=  5127[illegible]
// END

[illegible]JCF VIO OPERATING SYSTEM VERSION 1 REVISION C12 03/04/74 GENERATED  5/ 2/74


  JOB HANDLING CHARGE      [illegible]  .05 / JOB          .35
 131 LINES PRINTED PR1     [illegible] 1.05 / K LN         .14
  89 CARDS READ            [illegible] 1.50 / K CR         .13
  00 PLOTTER VECTORS       [illegible]  .05 / 1K V         .00
  20 MODEL 7  SECONDS      [illegible]  .05 / SEC          .10
  00 MODEL 4  SECONDS      [illegible]  .05 / SEC          .00
                           TOTAL CHARGES                   .72


[illegible]ERREIR 49[illegible] 14/31  LOGGED OUT 23/ 9/75  2:5[illegible]  $  15.66 LEFT AFTER  [illegible]5 LOGINS
```

Now we see that with an assumed value Z1 = 35 we obtain

S = 215.1808

BOT = 3.686 so Z1 actual = 58.38

TSBH = 47512.793 (too high)

TSBS also too high

The Z1 actual value obtained suggests that we should have assumed an higher Z1 value and with an assumed value Z1 = 40 we then obtain

S = 203.626

BOT = 4.428 so Z1 actual = 45.98

TSBH = 34131.855 (too high)

TSBS also too high

This suggests an assumed Z1 value higher than 40 but now we may interpolate with the two results already obtained and determine the Z1 value that will bring TSBH = DSC = 30000 psi and done properly this new Z1 assumed will end up being Z1 actual. From interpolation we obtain

$$Z1 = 40 + \frac{(40-35)*(34131.855-30000)}{(47512.793-34131.855)} = 41.544$$

and now assume this value obtaining the following result:

```
0'E4      C       *AL* IS THE LE[illegible]T
0 E4              AL=1.[illegible] .
0'EC              R=AL/5.75
0'18      C       *DRA* IS THE DRAFT
0'18              DRA=[illegible]/3.2
0'24              D=AL/14.
0.3[illegible]    C       *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0.30      C       FOR STEEL
0'3[illegible]              POI=0.3
0'3[illegible]    C       *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0'3[illegible]    C       FOR STEEL
0'3[illegible]              E=3[illegible].*1[illegible].***6
0 4C      C       *DST* IS THE DESIGN STRESS IN TENSION
0'4C              DST=2[illegible]  .
0'54      C       *DSC* IS THE DESIGN STRESS IN COMPRESSION
0 54              DSC=[illegible]  .
0'5C      C       *M* IS THE BENDING BENDING MOMENT
0 5C              M=1.3714[illegible]*DRA*AL**[illegible]
0'74      C       *SM* IS THE SECTION BENDING MOMENT
0'74              SM=[illegible]*DR  /[illegible]*AL
0 8[illegible]              I=[illegible].3[illegible]*(1.-POI*[illegible])*DSC/E
0 A[illegible]              L=SQRT( )
0 B4              Z=1./L
0 C[illegible]    *HTOP* IS THE HEAD OF WATER ON DEC[illegible]
0 C[illegible]              HTOP=2.
0 C[illegible]    *HBOT* IS THE  HEAD OF WATER ON BOTTOM
0'C[illegible]              HBOT=DR
0 DC              STRSI=2.15222[illegible]*HTOP*Z+7
0 E4              Z1=4.[illegible]*[illegible].**4131.[illegible]55/1[illegible]8  .938
0 E[illegible]              STRS[illegible] =[illegible].15222[illegible]*HBOT*Z1*Z1
01AC              A=DST-.1631
0'1[illegible]              AB=DSC-STRSI
0124              AC=(AB*(E+I)-A*I)/(A*I)
015C              AD=B*(  +C)/(2.*[illegible]*(3*L+2.*B*D))
0'A[illegible]              AE=(3.*  *D+2.*B*D)/(  *L+2.*B*D)
0'E4      C       *TOP* IS THE THICKNESS OF THE TOP PLATING
0'E4      C       *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
0'E4              BOT=AC/(1.+AC*AE)
02[illegible]C              TOP=AC*BOT
0218              WRITE(5,10)TOP
0234          10  FORMAT('1',22X,'TOP='F1[illegible].4)
024E              WRITE(5,20)BOT
026A          20  FORMAT(' ',22X,'BOT='F1[illegible].4)
0284      C       *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0284              S=Z*TOP
0290              WRITE(5,30)S
02AC          30  FORMAT(' ',22X,'S='F1[illegible].4)
02C4              R=2.*D+.BOT+R*(TOP+BOT)
02E8      C       *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02E8              DITOP=[illegible](R*BOT+.*BOT)/R
02[illegible]C              WRITE(5,40)DITOP
0328          40  FORMAT(' ',18X,'DITOP='F10.4)
```

```
     STRENGHT OF SHIPS-ON THE  EUTRAL AXIS LOCATION                    PAGE    2

0344      C       .DIBOT. IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
0344              DIBOT=(B*TOP+ *BOT)/
0368              WRITE(5,5 )DIBOT
0384          5   FORMAT(' ',19X,'DIBOT='F10.4)
03AC      C       *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT  .A.
03C0              GMI=4.*(*I*((0.*T**3+2.*D)*TOP*BOT+(D*D+2.*B*T)*BOT*B T)/D
0410      C       *ISTH*IS THE STRESS O  TOP DUE TO BOGGING
0418      C       *ISTS*IS THE STRESS O  TOP DUE TO SAGGING
0420      C       *TSBH*IS THE STRESS O  BOT DUE TO BOGGING
0428      C       *TSBS*IS THE STRESS O  BOT DUE TO SAGGING
0430      C       *STCRIT* IS THE CRITICAL STRESS ON TOP
0438      C       *SBCRIT* IS THE CRITICAL STRESS ON BOT
0440              TSTH=M *DITOP/G I+STBOT
0424              TSTS=S *DITOP/G I+STBOT
0468              STCRIT=I *TOP*.3/(.3396*S*S*(1.-P I*POI))
0478              WRITE(5,6 )TSTH
0494          6   FORMAT(' ',19X,'TSTH='F10.3)
04AE              WRITE(5,7 )TSTS
04CA          7   FORMAT(' ',19X,'TSTS='F10.3)
04E4              WRITE(5,8 )STCRIT
04FC          8   FORMAT(' ',17X,'STCRIT='F10.3)
0510              TSBH=M *DITOP/G I+ .1*2222*MBOT*S*S/(BOT*BOT)
0558              TSBS=S *DITOP/G I+ .1*2222*MBOT*S*S/(BOT*BOT)
0594              SBCRIT=BOT*BOT*.3/(.3396*S*S*(1.-P OI*POI))
05D4              WRITE(5,9 )TSBH
05EC          9   FORMAT(' ',19X,'TSBH='F10.3)
0604              WRITE(5,10 )TSBS
0626         10   FORMAT(' ',19X,'TSBS='F10.3)
0640              WRITE(5,11 )SBCRIT
065C         11   FORMAT(' ',17X,'SBCRIT='F10.3)
0678              END

0 [S] .U        0670[V] AL      0694[V] B       06C0[V] DRA     0594[V  D
38[V] BOI       06A4[V] E       06C0[V] .B      06E4[V] DST     06FC[V  DSC
C4[V] MM        0600[V] SM      0600[V] W       06FC[V] U       0000[S  SQRT
E [V] Z         06E4[V] STOP    06FC[V] WBOT    0613[V] STEST   0625[V  Z1
30[V] ST38      0710[V] A       0714[V] AB      0718[V] AC      072C[V  A
4 [V] AE        0748[V] BC1     074C[V] TOP     0234[L] 10      0000[S  PI
6 [L] 20        0750[V] S       0754[L] 30      07E4[V] P       0758[V  DITOP
2 [L] 40        0750[V] DIBOT   3854[L] 50      0762[V] GMI     076C[V  TSTH
7 [V] TSTS      0774[V] STCRIT  0494[L] 60      04CA[L] 70      0540[L  80
7 [V] TSBH      077C[V] TSBS    0782[V] SBCRIT  05E0[L] 90      0626[L  100
5C[L] 110       0000[S] .V

NO ERRORS
END OF PASS 2


PROGRAM LABELS:
2000 *MAIN*     2FCA .V         2D3A .COMP      29DC ALOG       2F1E @I         27F4 .P
2E02 .ZERO      2164 .E         2834 .A         2F5F .MES       2CDC .N         2AE4 EX
2C6A AINT       28F4 SQRT       2AA2 .PAWG      2DFF .5         2AF4 AEXP       2E06 .T
2DD4 *8         2F0E .L         2EDC .U         4734


ENTRY-POINTS:
```

```
TCP=      3.3 55
ROT=      4.7414
S=      193.60
DITOD=     40.0312
DIRCT=     31.3967
TSTI=   2499.0 3
TSTS=   1042 .516
STCKIT=  2990 .0 2
TSP ==  3,1 1 .643
TSIG=   2581 .4 4
SRCKIT=  619 .123
```

C* VIO OPERATING SYSTEM VERSION 1 REVISION 12 3/24/74 GENERATED 5/29/74

```
CR HANDLING CHARGE      1    .35 / JOB          .35
131 LINES PRINTED FOR   1  1.05 / 1 LINE       .16
89 CARDS READ           1  1.33 / 1 CARD       .13
CR PLOTTER VECTORS      1    .05 / 100 VECTORS  .00
22 MODEL 70 SECONDS    $25.00 / 1.5 MIN        .15
12 MODEL 50 SECONDS    $12.00 / 1.0 MIN        .07
                        TOTAL CHARGES          .79
```

VEIR 400 14731 LOGGED OUT 05/29/74 03:01. $ 14.87 LEFT AFTER .6 LOGINS.

We see that TSBH is just a little too high and the same happens with TSBS; here it might be the case that TSBS should have been the one under consideration for the choice of a Z1 value. Nevertheless for the purpose of this work this example shows the procedure to be used along with the equation derived. The accuracy obtained can be total. Here we assumed Z1 = 41.544 and ended up with Z1 actual = 41.83 which is close enough for our purpose and TSBH and TSBS is very close to what it should be to use the material effectively.

```
0004     C      *AL* IS THE LENGHT
0024           AL=1000.
002C           B=AL/5.75
0018     C      *DRA* IS THE DRAFT
0018           DRA=B/3.3
0024           D=AL/14.
0030     C      *POI* IS THE POISSON'S RATIO OF THE MATERIAL
0030     C      FOR ALUMINUM
0030           POI=0.33
0038     C      *E* IS THE YOUNG'S MODULUS OF THE MATERIAL
0038     C      FOR ALUMINUM
0038           E=10.*1.**6
0040     C      *DST* IS THE DESIGN STRESS IN TENSION
0040           DST=25.2.
0054     C      *DSC* IS THE DESIGN STRESS IN COMPRESSION
0054           DSC=9.2.
005C     C      *HM* IS THE HOGGING BENDING MOMENT
005C           HM=1.37143*B*DRA*AL*AL
0074     C      *SM* IS THE SAGGING BENDING MOMENT
0074           SM=B*DRA*AL*AL
0088           A=0.39296*(1.-POI**2)*DSC/E
009A           U=SQRT(A)
00B4           Z=1./U
00C0           *HTOP* IS THE HEAD OF WATER ON DECK
00C0           HTOP=B.
00C8           *HBOT* IS THE HEAD OF WATER ON BOTTOM
00C8           HBOT=DRA
00D0           STR3T=7.158222*HTOP*Z*Z
00E4           STR3B=7.158222*HBOT*Z*Z
00F8           AT=DST-STR3T
0104           AB=DSC-STR3B
0110           AC=(AT*(B+D)-A*D)/(A*B)
0140           AD=HM*(B+D)/(A*4.*D*(D*D+2.*B*D))
0194           AE=(3.*B**2+2.*B*D)/(D*D+2.*B*D)
01E0     C      *TOP* IS THE THICKNESS OF THE TOP PLATING
01E0     C      *BOT* IS THE THICKNESS OF THE BOTTOM PLATING
01E0           BOT=AD/(1.+AC*AE)
01F8           TOP=AC*BOT
0204           WRITE(5,10)TOP
0220        10 FORMAT('1',20X,'TOP='F10.4)
023A           WRITE(5,20)BOT
0256        20 FORMAT(' ',20X,'BOT='F10.4)
0270     C      *S* IS THE SPACING OF LONGITUDINAL STIFFENING MEMBERS
0270           S=Z*TOP
027C           WRITE(5,30)S
0298        30 FORMAT(' ',22X,'S='F10.4)
02B0           P=2.*D*BOT+B*(TOP+BOT)
02D4     C      *DITOP* IS THE DISTANCE OF THE TOP FROM THE NEUTRAL AXIS
02D4           DITOP=D*(B*BOT+D*BOT)/P
02F8           WRITE(5,40)DITOP
0314        40 FORMAT(' ',18X,'DITOP='F10.4)
0330     C      *DIBOT* IS THE DISTANCE OF THE BOTTOM FROM THE NEUTRAL AXIS
```

STRENGHT OF SHIPS-ON THE NEUTRAL AXIS LOCATION PAGE 2

```
0330            DIBOT=D*(B*TOP+D*BOT)/P
0354            WRITE(5,50)DIBOT
0370         50 FORMAT(' ',10X,'DIBOT='F10.4)
038C      C     *GMI* IS THE MOMENT OF INERTIA OF THE X SECTION ABOUT N.A.
038C            GMI=4.*D*D*((3.*B*B+2.*B*D)*TOP*BOT+(D*D+2.*B*D)*BOT*BOT)/P
03FC      C     *TSTH*IS THE STRESS ON TOP DUE TO HOGGING
03FC      C     *TSTS*IS THE STRESS ON TOP DUE TO SAGGING
03FC      C     *TSBH*IS THE STRESS ON BOT DUE TO HOGGING
03FC      C     *TSBS*IS THE STRESS ON BOT DUE TO SAGGING
03FC      C     *STCRIT* IS THE CRITICAL STRESS ON TOP
03FC      C     *SBCRIT* IS THE CRITICAL STRESS ON BOT
03FC            TSTH=HM*DITOP/GMI+S*R3T
0412            TSTS=SM*DITOP/GMI+S*R3T
0424            STCRIT=TOP*TOP*E/(1.3@396*S*S*(1.-POI*POI))
0464            WRITE(5,60)TSTH
0480         60 FORMAT(' ',10X,'TSTH='F10.3)
049A            WRITE(5,70)TSTS
04B6         70 FORMAT(' ',10X,'TSTS='F10.3)
04D0            WRITE(5,80)STCRIT
04EC         80 FORMAT(' ',17X,'STCRIT='F10.3)
0508            TSBH=HM*DIBOT/GMI+2.152222*HBOT*S*S/(BOT*BOT)
0544            TSBS=SM*DIBOT/GMI+2.152222*HBOT*S*S/(BOT*BOT)
0580            SBCRIT=POI*BOT*E/(1.3@396*S*S*(1.-POI*POI))
05C0            WRITE(5,90)TSBH
05DC         90 FORMAT(' ',10X,'TSBH='F10.3)
05F6            WRITE(5,100)TSBS
0612        100 FORMAT(' ',10X,'TSBS='F10.3)
062C            WRITE(5,110)SBCRIT
0648        110 FORMAT(' ',17X,'SBCRIT='F10.3)
0664            END
0[S] .U         0668[V] AL      0674[V] B       0678[V] DRA     0680[V] D
8[V] POI        0690[V] E       0000[S] .R      069C[V] DST     06A4[V] DSC
C[V] HM         06B4[V] SM      06B8[V] W       06C4[V] U       00D0[S] SQRT
8[V] Z          06CC[V] HTOP    06D4[V] HBOT    06D8[V] STR3T   06E4[V] STR3B
4[V] A          06E8[V] AB      06EC[V] AC      0700[V] AD      0714[V] AE
C[V] BOT        0720[V] TOP     0224[L] 10      0000[S] @I      0256[L] 20
4[V] S          0298[L] 30      0728[V] P       072C[V] DITOP   0314[L] 40
0[V] DIBOT      037C[L] 50      0734[V] GMI     0740[V] TSTH    0744[V] TSTS
8[V] STCRIT     0480[L] 60      04B4[L] 70      04EC[L] 80      074C[V] TSBH
0[V] TSBS       0754[V] SBCRIT  05DC[L] 90      0612[L] 100     0648[L] 110
7[S] .V
XEQ         L
=
```

```
OGRAM LABELS:
2070 *MAIN*   2EDE .V      2DCE .COMP    29B0 ALOG     2EEC @I       27C8 .R
2DD6 .ZERO    2D34 $6      2809 .A       2E32 .MES     2CB0 .W       2AB8 EXP
2C3E AINT     28BA SQRT    2D76 .FARG    2DD2 .5       2AB8 AEXP     2DDA .ER
2DA8 $8       2DDA .0      2EB0 .U       4008

RY-POINTS:
27C8 .R       2808 .A      28BA SQRT     29B0 ALOG     2AB8 AEXP     2AB8 EXP
```

```
          TOP=     2.9992
          BOT=     3.7608
            S=   105.2122
       DITOP=    38.4761
       DIBOT=    32.9524
        TSTH= 24999.988
        TSTS=  1[illegible]35.031
      STCRIT=  3[illegible]0.774
        TSPH= 24476.747
        TSPS=  2 954.855
      SRCRIT= 47172.344
 END

CF VIC OPERATING SYSTEM VERSION 1 REVISION  012 03/04/74 GENERATED  05/02/74  0

 JOB HANDLING CHARGE    $   .35 / JOB          .35
 130 LINES PRINTED PER  $  1.25 / K LN         .16
  88 CARDS READ         $  1.50 / K CD         .13
  70 PLOTTER VECTORS    $   .25 / 1 K          .02
  15  CORE 72 SECONDS   $25.00 / HOUR         .10
  70  CORE 32 SECONDS   $12.50 / HOUR         .02
                        TOTAL CHARGE $         .74

RREIR 492 14731  LOGGED OUT 03/09/74 02:45.  $  17.18 LEFT AFTER    13 LOGINS.
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This last example shows that TSBH is low and the Z approximation used in the formulas here again should be corrected as already exemplified in order to bring it closer to the DSC value.

CONCLUSION

From this work the author is led to conclude that there is no simplified approach to the neutral axis location in the midship section, capable of handling properly all or only a majority of cases. It is advisable to look into each particular situation by first gaining some insight at what the diagrams of stress distributions may look like as exemplified in several sections. The two last sections exemplify well why this may be of some advantage and specially the last section which shows that while at first it was expected for the examples studied a neutral axis closer to the top, actually the results ended up requiring a neutral axis closer to the bottom and a new set of formulas had to be derived.

As a future development for this work it is here suggested that a more ship like cross section could be analysed as a step forward towards obtaining a method of determination of scantlings as direct as possible. This next step should consider the derivation of proper formulas for DITOP, DIBOT and I involving only the plate thicknesses as unknowns. It should be considered then, in order to simplify the problem., a standard type of frame and its scantlings should be constant throughout the midship section.

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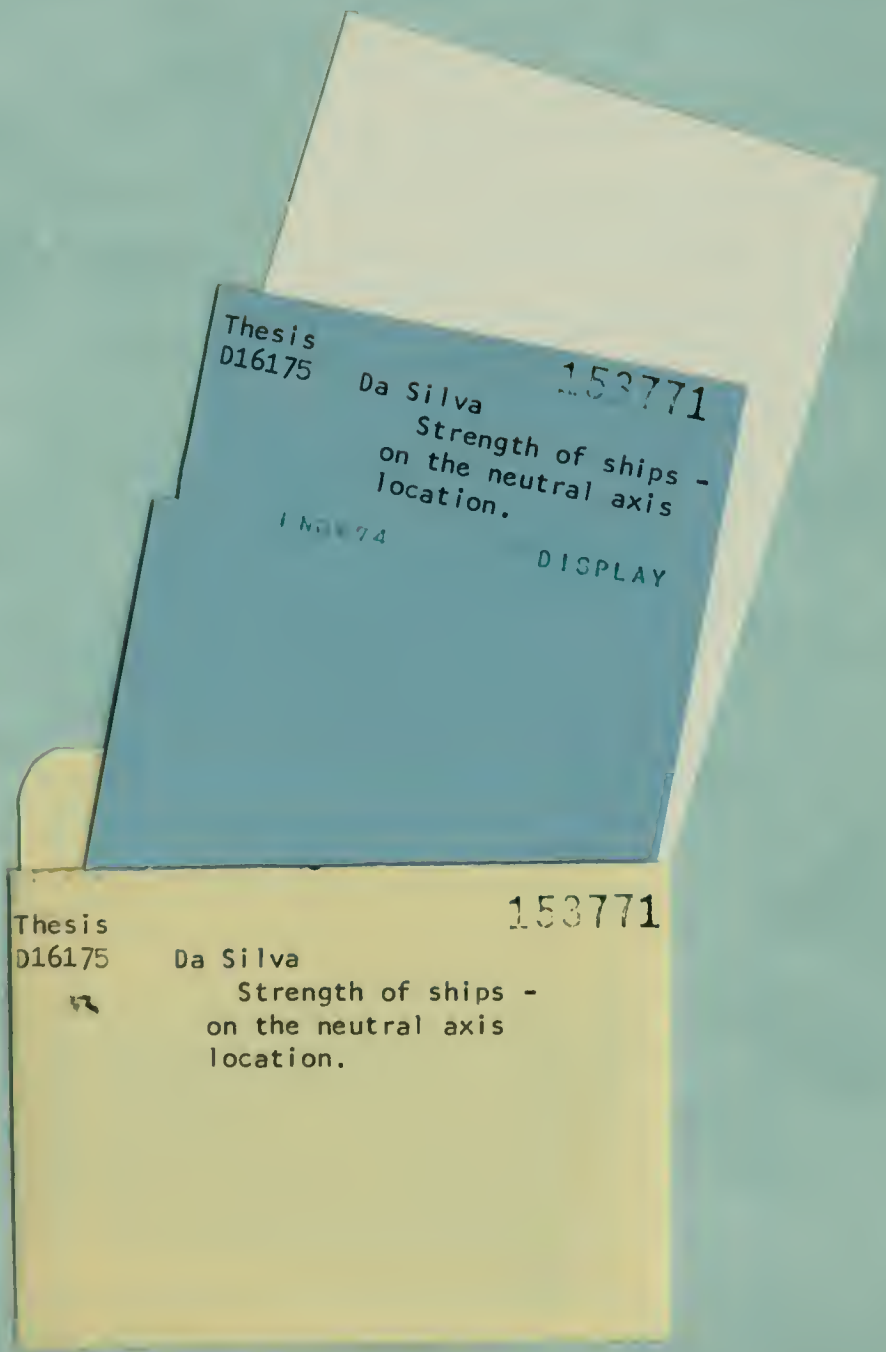
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location.
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